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SURVEY OF MULTIPLE CROPPING IN LESS DEVELOPED NATIONS

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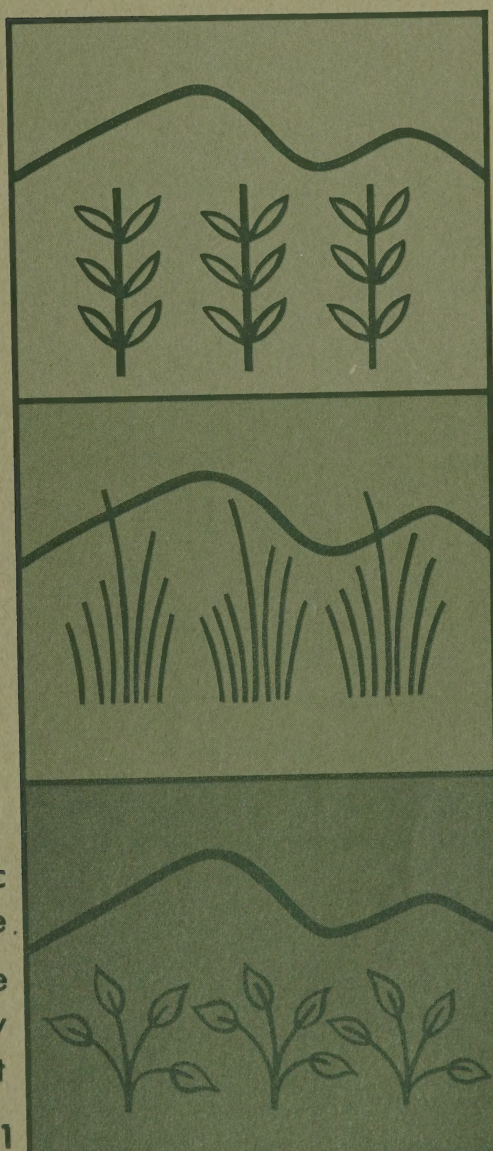

U.S. Foreign Economic Development Service.

U.S. Department of Agriculture cooperating with U.S. Agency for International Development

FEDR-12 October 1971

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ABSTRACT

Multiple cropping is the practice of growing more than one harvested crop in sequence on the same piece of land in the course of one year. It is sometimes commonly known as double and triple cropping.

While an ancient technique in many parts of the world, multiple cropping is of current importance because of the promise it holds for alleviating important contemporary problems in the less developed nations. It can help make possible increases in total agricultural output, the variety and quality of food, rural employment, and small-holder income.

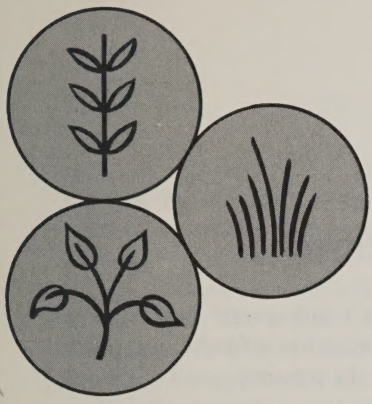
Recent technological advances in developing short-season varieties have both (1) broadened the area of the world where multiple cropping is possible, and (2) increased the potential number of crops which may be grown in current multiple cropping areas. But to take advantage of multiple cropping, adequate water control must be available (which generally means irrigation), along with farm chemicals and improved farm management.

The point at which it is economically and socially desirable to leave traditional single cropping methods and to shift into multiple cropping is not easy to determine. Both social and private factors must be considered: the government planner will be concerned whether multiple cropping is the best use of resources from society's point of view; the farmer will be concerned with profitability.

Many difficult questions will have to be answered if multiple cropping is to be of maximum benefit. They cannot be fully answered yet, because research on multiple cropping has only recently begun to get underway. Still, planners and other government officials will have to begin to make important decisions pertaining to multiple cropping.

Essentially no general comprehensive information on multiple cropping on a global scale has been available. This report is an attempt to correct that situation. It surveys the development and current status of multiple cropping in the less developed nations. Hopefully it will provide the background which will help others ask the most appropriate questions in future research, and at the same time be of interim assistance to policy makers.

KEY WORDS: Intensive agriculture, Double cropping, Triple cropping, Cropping systems, Cropping indexes, Rotations, Irrigation, Green revolution, Developing nations.



SURVEY OF MULTIPLE CROPPING IN LESS DEVELOPED NATIONS

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RELATED INVESTIGATIONS

This bulletin is an outgrowth of two studies I did several years ago on diversification and technological change. If the reader has a further interest in these closely related areas, he may wish to refer to the reports:

The Diversification of Agricultural Production in Less Developed Nations, International Agricultural Development Service, U.S. Department of Agriculture, August 1968, 56 pp. (This report in turn was an outgrowth of a study on potato industry in East Pakistan in 1967 which is noted in the text.)

Technological Change in Agriculture: Effects and Implications for the Developing Nations, Foreign Agricultural Service, U.S. Department of Agriculture, April 1969, 82 pp. (The subject was also discussed in "New Technology: Rose and Thorn," 1970 Yearbook of Agriculture, pp. 298-307.)

Both bulletins are available from the Foreign Economic Development Service.

FOREWORD

Multiple cropping is a matter of increasing interest in many less developed nations. But despite a long history and growing importance, no comprehensive report on multiple cropping has existed. What few studies are available generally focus on some technical aspect in the context of one country.

The reasons for the lack of more general study, one soon learns, are not hard to find. The subject is vast and complex. Little solid research exists. Data are scarce and hard to find. Few agricultural scientists in the developed countries have given the matter much thought.

Yet the importance of the subject, plus the difficulties involved in preparing a general survey, provided an irresistable lure. The result is this report. It is intended to provide a review of the historical development and current status of multiple cropping in less developed nations. Although fairly detailed, the study, in due deference to the subject, cannot be said to be more than an introduction.

The report is marked by two particular characteristics which should be acknowledged at the outset:

– First, it largely approaches the subject from the point of a government agricultural economist. Members of other disciplines, as well as other economists, might well handle the subject differently. Each will undoubtedly feel the need for further work in his area.

– Secondly, the report is basically a review of literature, supplemented by extensive international correspondence. Those with first-hand field experience in multiple cropping might prepare a different kind of report.

For these reasons it is highly desirable that others, in turn, explore different dimensions or provide additional perspective on multiple cropping. Perhaps this report will provide the broad background which will facilitate and stimulate further study.

It is hoped that the report will be of at least interim value to those concerned with the planning and operation of intensive agricultural programs in developing nations.

ACKNOWLEDGEMENTS

Many individuals assisted in the preparation of this report. Generally their contributions fell in one or more of three categories:

- Provision of information. Numerous persons provided data on specific points; they are usually mentioned in the footnotes. Among the groups which were most helpful were: U.S. agricultural attaches, AID food and agricultural officers, the Ford and Rockefeller Foundations, and the International Rice Research Institute. The staff and resources of the National Agricultural Library were of invaluable assistance.
- Technical review. Wherever possible, individual country sections were checked over by one or more of the persons cited in that section. Other portions, or all, of earlier versions of the manuscript were reviewed by the following individuals:

  Foreign Economic Development Service, USDA. Martin Kriesberg, Lyle Schertz, Robert Taylor (on leave from Purdue University).
  Economic Research Service, USDA. L.J. Atkinson, Harry Walters.
  Agricultural Research Service, USDA. C. Roy Adair, L.P. McCann and associates.
  Agency for International Development. Martin Billings (New Delhi), Lawrence Witt.
  Cornell University. Gilbert Levine.
  Iowa State University. Earl O. Heady.
  University of Minnesota. Vernon Ruttan.
  International Rice Research Institute. Gordon Banta, Randolph Barker, Richard Bradfield, Bart Duff.
  Ford Foundation. Dwight Finfrock (Bangkok), A.A. Johnson and associates (New Delhi).
  Rockefeller Foundation. Delane Welsch and associates (Bangkok).

- Preparation for publication. Assistance was provided by Helen Dalrymple, Delores Miles, and David Winkelmann.

Errors and oversights undoubtedly remain. I bear the responsibility.

CONVERSION FACTOR

1 hectare = 2.471 acres

CONTENTS

I. INTRODUCTION

In evaluating prospects for increasing or improving world food output, emphasis is traditionally placed on two dimensions: (1) expanding area, and (2) improving yield of individual crops.[1] Peculiarly, little has been said about a third possible dimension: time. It is possible to make fuller use of time by multiple cropping—the practice of growing more than one crop on the same piece of land in a year. Multiple cropping makes possible both an increase in area cultivated per year as well as an increase in total yield per unit of area per year.

THE ROLE OF MULTIPLE CROPPING

Although it might seem the most advanced of agricultural techniques, multiple cropping is in some ways an anomaly: it has an ancient history but its practice is still largely confined to the less developed nations. Multiple cropping was carried out well before the time of Christ in some countries. And currently immense areas are so cropped in Asia. Yet the area multiple cropped in the developed nations appears to be extremely small.[2]

There are, of course, good reasons for the present pattern of distribution. The more advanced nations are found in temperate climates which severely limit the possibilities for multiple cropping. It is possible for them to provide needed food supplies through traditional production channels or through imports. The developing nations, on the other hand, are located in tropical and semi-tropical areas, which provide more hospitable climates for year-round cultivation. Moreover, they are often more densely populated and living nearer the margin with respect to food supplies. For these reasons, multiple cropping has had to be employed.

Thus multiple cropping has more or less evolved over the centuries to meet local situations and conditions. It has not been the direct product of a formal scientific process, even though technological advances in other fields have contributed to its progress. In fact, multiple cropping until the last few years hardly seems to have been the subject of any kind of concerted attention.

The situation, however, is beginning to change. The continuing surge in population growth and critical crop failures in the mid-1960's led to a more general concern with the question of how long the less developed world could feed itself. More recently there has been increased concern with such social matters as the quality of diet, employment, and income. Multiple cropping, it is increasingly recognized, holds promise of making contributions on all these counts.

[1] For an example I need look no further than myself and a note on "Trends in Grain Area and Yield in Developed and Developing Nations," in the *American Journal of Agricultural Economics*, August 1970, pp. 448-449.

[2] Multiple cropping in the United States is discussed in Appendix A.

Concurrently with the growth of these concerns, a number of early-ripening, high-yielding varieties of wheat and rice were introduced which, in combination with vital inputs, have led to what is popularly known as the Green Revolution. Much of the discussion of these varieties is in terms of their immediate effect on output. But over the longer run, their greatest impact may come from the early ripening characteristics which often helps make it possible to plant an additional crop each season. Moreover, the inputs necessary for high yield are complementary to the needs of multiple cropping.

Research on multiple cropping itself is relatively new. At the international level, pioneering work has been done at the International Rice Research Institute (IRRI) in the Philippines. Two of the newer centers—the Centro Internacional de Agricultura Tropical (CIAT) in Colombia and the International Institute of Tropical Agriculture (IITA) in Nigeria—have also recently initiated studies in this area.[3] At the national level, the major research efforts are found in Asian countries; the biggest program is probably in India.

In view of the continuing need for agricultural output and economic growth in the less developed nations on one hand, and the new technical possibilities for multiple cropping on the other, the time seems at hand for a comprehensive international review of the background and current status of multiple cropping. Such a review could provide a framework for evaluating future prospects and for guiding emerging policy and research activities. Such is the purpose of this survey.

The report is broken into four main parts. The remainder of this introduction will briefly define terms and discuss statistical measures. Chapter II reviews the historical development of multiple cropping. Chapter III outlines the major biological and physical aspects of multiple cropping. Chapter IV analyzes some of the general social and economic considerations. Chapter V, the longest, reviews recent statistical data and cropping information for individual countries. Chapter VI, the last, discusses policy implications.

DEFINITION OF TERMS

The term multiple cropping can mean quite different things to different individuals. Many alternative cropping systems are possible. No one definition will cover all cases.

Multiple Cropping

In this report, multiple cropping will generally refer to a regular *sequence* of more than one annual food, feed or industrial crops both planted and harvested in the course of a twelve month period, and grown in basically pure stands on the same piece of land under a system of permanent agriculture.

This definition is, of course, arbitrary and excludes as much as it includes. It does not encompass green manure crops, mixed farming, shifting cultivation, and most forms of intercropping. Since these terms, too, can have different meanings, further explanation may be in order.

[3] *Annual Report, 1969*, Centro Internacional de Agricultura Tropical, Cali, Colombia, p. 44; letter from Dr. J. C. Moomaw, International Institute of Tropical Agriculture, Ibadan, Nigeria, June 4, 1971. The IITA work will be part of a Cropping Systems Program which will also include mixed cropping and intercropping.

Green Manure Crops. These crops are legumes which are grown for their soil improving qualities or as a cover crop and which are plowed in at the end of the growing season. They are not harvested and do not by themselves produce a food or feed crop. Hence they are conceptually excluded (although they may be included in some national statistics).

Mixed Farming. This practice can involve (a) the growing of annual crops under or with perennial crops (shrubs or trees),[4] and (b) both the growing of crops and the raising of livestock. Perennial crops are excluded because they are not planted and harvested in the course of one year.

Shifting Cultivation. This practice involves the clearing of wooded areas, cultivation of several crops a year until soil fertility is exhausted or weeds get out of hand, and then abandonment of the land to the surrounding forest. Clearly the land is not in permanent agriculture in this sort of system.[5]

Intercropping. In many tropical areas, more than one crop—in some cases dozens—is planted on a given piece of land.[6] The various crops may be planted at the same or different times. Usually, however, they are not planted in sequence.[7] Where intercropping involves only a few crops, several variants arise which could be counted as forms of multiple cropping:

— Perhaps the most easily included case is relay interplanting. This practice is rather widely used and involves the sowing or planting of a second crop between the rows of the first crop before it is harvested. Thus the crops may overlap for a short period, say a few weeks. This practice is frequently necessary to fit the multiple cropping pattern into the available growing season.

— Less clear-cut cases involve (a) relay interplanting where the period of overlap is rather extended (say several months) or (b) interplanting with crops having different maturation periods. An example of the first is the interplanting of soybeans a month or two after cotton; the harvest periods are similarly differentiated.[8] An example of the second involves the

[4] Sometimes these combinations can get quite complicated. In the Philippines, for instance, vegetables may be grown between rows of pineapples grown under papaya trees interplanted with coconut trees (Jose M. Lawas, "Agricultural Diversification and Development: The Philippine Viewpoint," SEADAG paper No. 71-3 (The Asia Society, New York), p. 9.

[5] This practice is sometimes referred to as slash and burn or swidden agriculture. Shifting agriculture is the dominant form in tropical Africa. It extends over 14 million square miles and involves 200 million people. Almost no permanent field agriculture is found in a broad belt running across the middle of the continent. (Marvin P. Miracle, *Agriculture in the Congo Basin,* University of Wisconsin Press, 1967, p. 33.) For detail see: Pierre de Schlippe, *Shifting Cultivation in Africa; The Zande System of Agriculture,* Routledge and Kegan Paul, London, 1956, 304 pp.; Colin Clark and Margaret Haswell, *The Economics of Subsistence Agriculture,* St. Martins Press, 1964, pp. 32-47. Also see J. E. Spencer, *Shifting Cultivation in Southeastern Asia,* University of California Press (Publications in Geography, Vol. 19), 1966, pp. 110-135.

[6] At some stages during cultivation of a clearing as many as 50 crops may be found growing together (C.C. Webster and P.N. Wilson, *Agriculture in the Tropics,* Longmans Green & Co., London, 1966, p. 165).

[7] For an excellent discussion of mixed cropping see D.W. Norman, "Intercropping of Annual Crops Under Indigenous Conditions in the Northern Part of Nigeria," Ahmadu Bello University (Samaru, Zaria, Nigeria), Institute for Agricultural Research, Rural Economy Research Unit, March 1971, 14 pp. (mimeographed).

[8] Arwooth Na Lampang, "Soybeans as a Second Crop for Thailand," presented at SEADAG Rural Development Panel Seminar, Manila, January 7, 1971, p. 5.

simultaneous planting of two or three grains with different maturity and harvest periods. Whether these two practices should be considered multiple cropping is a moot point; I would tend to exclude them.

Intercropping is sometimes carried out simultaneously with intercropping.[9]

Other Exclusions. There are several other agricultural practices which are conceptually excluded. In some settled regions, several crops may be raised on a given piece of land each year for several years, and then the land left fallow for one or more years before being cropped again; this practice is not included because the land is not cropped every year.[10] Elsewhere, ratooning—the practice of letting a second crop grow up from the root structure of the first crop—is practiced; it doesn't quite meet the definition used here because a separate planting process is not involved (moreover, the yield of the second crop may be relatively low) but could easily be considered a type of multiple cropping.

Thus we see that the definition of multiple cropping used here has many exclusions. Still, what does remain reflects a practice which is in widespread use throughout the world. We now turn to a closer look at that system.

Multiple Cropping Systems

Multiple cropping in practice may involve the cultivation of from two to as many as nine crops in sequence on the same piece of land in a year. Double cropping is by far the most common, but triple and quadruple cropping are not unusual. Multiples higher than this usually involve a pure rotation of vegetables and are found in very limited market garden areas.[11] Our emphasis will be placed on the lower multiples which are usually developed around a grain crop.

Varying crop combinations have led to three major forms of multiple cropping rotations. For lack of better terms at the moment, they might be called monoculture, duoculture, and polyculture.

– Monoculture. This involves a sequence of the same crop, such as corn after corn. Combinations of this type are generally not widely used because of biological and cultural problems which will be discussed later. An exception is provided by rice which is often double, and in some cases triple, cropped.[12]

– Duoculture. This category is considerably more common and involves sequences of the same types of crops, such as grain after grain or vegetable after vegetable. The grain combination might, for instance, involve rice and

[9] A Nigerian example is reported in Chapter V.

[10] Boserup also excludes such culture from her definition of multiple cropping (Ester Boserup, *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*, Aldine, 1965, p. 16).

[11] The highest numbers of crops noted were for the Dalat area in Vietnam and Hong Kong. In Dalat, an estimated 30% of the vegetable growers raise 9 crops per year (2 or cabbage, 1 of cauliflower, and 6 of lettuce) while the other 70% raise 6 crops. In Hong Kong in 1961-65, about 45% of the growers planted 7 to 9 crops; 80% raised over 4 crops. (C.L. Luh, "Report on Vegetable Production Survey in Southeast Asian Countries," Seminar on Food Problems in Asia and the Pacific, Honolulu, May 1970, pp. 12-13; *Provisional Indicative World Plan for Agricultural Development*, FAO, Vol. I, August 1969, p. 203.)

[12] Some examples of high-yielding triple cropping rotations are provided in Appendix B.

wheat or wheat and millet. The vegetable category is wide open due to the large number of varieties and may involve innumerable combinations.

– Polyculture. This group includes combinations of different types of crops such as grain and pulses, grain and vegetables, grain and cotton, vegetables and pulses, etc. These combinations are also fairly common.

The possible number of combinations and rotations climbs geometrically as the frequency of multiple cropping increases. Where the frequency is high, and multiple cropping is widely practiced, such as on Taiwan, a wide variety of sequences are found. Different sequences may even be found on the same farm.

MULTIPLE CROPPING STATISTICS

The statistics on multiple cropping take two main forms: the actual area planted and the multiple cropping index. The cropping index provides a measure of the relative extent of multiple cropping. In most cases the area data presented in this report are taken from official government statistics. Sometimes cropping indexes are reported, but more generally they have been calculated. Interpretation of each series requires some knowledge of their derivation and limitations.

Area Multiple Cropped

It is not easy for a nation to determine the amount of area actually multiple cropped. To gain an accurate picture, crop reporting surveys should (a) be made for each of the seasonal planting periods, or (b) where only an annual survey is carried out, an attempt made to find the area planted in each of the multiple cropping rotations. Either could be especially difficult where there is a wide variety of rotations with different time periods in the same country or region. A further complication is added when even limited intercropping is carried out.

Unfortunately we do not know much about how most of the cropping data presented in this report were gathered. Some insights are available, however, for two nations with relatively highly developed crop reporting systems: India and Pakistan. Both base their information on surveys which are conducted one or more times a year.

Some of the major problems in India, as garnered from a report by the Indian Government,[13] seem to be as follows: (1) the number of surveys varies by states—ranging from 1 in one state to 12 in another; (2) the questions refer only to the area cropped more than once, which could well lead to underreporting; and (3) the definition of cropping more than once is not uniform. Even classification of grain intercropping presents difficulties.[14] Recommendations for improved procedures of reporting were presented at a

[13] *Land Records and Agricultural Statistics,* Ministry of Agriculture, Directorate of Economics and Statistics, New Delhi (1970?), pp. 277, 405-410.

[14] In studying a village in Uttar Pradesh, Chauhan found that according to the traditional practice of reporting intercropped land only once, the cropping index for 12 farms was 106.1. Yet when the grain intercropping was sorted out, the index became 131.7. (D.S. Chauhan, "Index of Crop Intensity," in: his *Studies in Utilization of Agricultural Land,* Shiva Lal Agarwala & Co., Agra, 1966, pp. 166-175; *Journal of Social Sciences,* January 1958, pp. 22-32.)

national seminar on multiple cropping in New Delhi in May 1970 and further spelled out in a recent report on benchmark and evaluation needs of a pilot program in multiple cropping.[15]

A related problem was unearthed in Pakistan in the course of this study. Review of data for recent years showed some puzzling trends. Upon investigation it appeared that the published data reported only the land cropped more than once in one of the two seasons. Thus the multiple cropped area for the year was underreported. This problem has now been recognized and revised data are being prepared.[16]

In view of problems of this nature, the area statistics presented in this report should be viewed with more than a little reservation.

Index of Multiple Cropping

The extent of multiple cropping is commonly expressed, in quantitative terms, as an index. The index is derived by dividing the total land area planted during the year (including that planted as a result of multiple cropping) by the amount of cultivated land physically available and in use. The exact terminology of the ratios varies somewhat between countries: in India it is total cropped area divided by net area sown; in Japan it is total area planted to all crops as a proportion of cultivated field area; for China it is sown area divided by cultivated area.

Perhaps an example involving double cropping would clarify the point.[17] Assume that in a given country, 2 million hectares were planted (sown) including area double cropped. In the same year, assume that a maximum of 1.5 million acres of cultivated land were in use. The multiple cropping index (MCI) would be 2 divided by 1.5, or 1.33 (herein expressed as 133).

The total area planted may, of course, be obtained by adding the additional area resulting from multiple cropping—i.e. the area in the second and third crops—to the total cultivated land physically in production. In the above case, this means adding 0.5 million acres from double cropping to 1.5, producing a total of 2.0 million acres.

In a different context, one could say, again using this example, that 1.0 million acres are single cropped and that 0.5 are double cropped. The total cropped area is obtained by multiplying 0.5 by two (to represent the first and second crops) and then adding to 1.0, giving 2.0. Or, one could say that the double cropped area is 33% of the sown area.

[15] *Report of the National Seminar on Multiple Cropping*, pp. 1-4; "Benchmark Survey and Evaluation in Multiple Cropping Pilot Project Blocks," Ford Foundation, New Delhi, 1971 (sample survey forms are included). The multiple cropping program in India will be described in greater detail in the section on India in Chapter V.

[16] This matter is discussed in further detail in the Pakistan section of Chapter V of this report.

[17] In actual practice, the index does not reflect the exact amount of double cropping if triple, quadruple, or other multiple cropping practices are also utilized. A smaller area triple cropped could produce the same statistical result as a larger area double cropped. Hence the index may reflect only the aggregate of several intensities of multiple cropping.

To summarize the example in tabular form:

a. Sown area	2.0 million acres
b. Cultivated area	1.5
c. Cultivated area double cropped	0.5
d. Cultivated area single cropped	1.0
e. Multiple cropping index.	1.33 (or 133)

Or, to summarize the calculations in algebraic terms:

$a = b + c$, or $2c + d$
$b = c + d$
$c = a - b$
$d = b - c$

$$e = \frac{a}{b}$$

It may be that some of the national multiple cropping indexes cited in this report are—unknown to me—not calculated in quite this way. In any case, as we will see, the indexes may be quite different for individual areas within a nation.

Problems in Interpretation

In addition to the reporting and calculation difficulties associated with multiple cropping statistics, several problems of interpretation may arise. Two which are worthy of special mention concern yield comparisons and measurement of land use intensity.

Yield Comparisons: Under multiple cropping emphasis is on total output for the year rather than maximum output for individual crops. Hence it is unrealistic to make yield comparisons for individual crops involved in multiple cropping rotations, especially if the comparison is drawn with a country or region where only one crop is grown a year. This means that any individual crop comparison involving a country like Taiwan, which has a very high multiple cropping index, is relatively meaningless (unless possibly the comparison is for relative growth rates in yield over a period in time). The error is, of course, reduced with lower multiple cropping indexes—but it still exists.

A more subtle but similar problem is involved in making comparisons between countries which both practice multiple cropping. In the past, some have attempted to compare rice yields between Japan and Taiwan. The problem here is that in Japan multiple cropping is usually limited to double cropping with something other than rice raised during the second season. On the other hand, rice is often raised twice a year in Taiwan on the same piece of land, which may further be planted to one to three other crops.[18]

In one sense, it would be more appropriate to make comparisons on the basis of total output per unit of area per year, but this could run into

[18] This problem was recognized, however, by Yujiro Hayami and Saburo Yamada in "Agricultural Productivity at the Beginning of Industrialization," in *Agriculture and Economic Growth: Japan's Experience* (ed. by K. Ohkawa, et al.), Princeton University Press and University of Tokyo Press, 1969, p. 107.

complications because of the different types of crop combinations involved where multiple cropping is practiced. Another possibility would be to translate the output into value terms, but this would be going way beyond the capabilities of almost any general crop reporting system.

Measuring Land-Use Intensity: Although multiple cropping indexes may generally be closely associated with cropping intensity, they cannot be taken as a very fine measure of intensity of land use. The reason is that each crop has a different growing season; some, such as sugarcane or pineapple, may require a year or more. Thus if multiple cropping just means the substitution of two shorter-season crops for one longer season crop, the intensity of land use is not increased even though the cropping index may be doubled (and labor use increased if the crops are more labor intensive). Similarly, land use intensity is not necessarily lowered if one long season crop is substituted for two shorter season crops (though again the intensity of labor use may be altered).

Several proposals have been made which would provide a more adequate measure of land use intensity. M. M. el Iman, in a study published in 1962, proposed the use of an exploitation area measure which would take into account length of growing seasons.[19] Biological scientists have for some time considered the idea of measuring total photosynthesis utilization per unit of land, whether this be in the form of sequential crops or crops left standing throughout the year. The problem with these approaches is a measurement one: it would be necessary to have considerably more statistics than are presently available for most countries. The time may come, however, when these more detailed measures are needed.[20]

[19] M. M. el Iman, *A Production Function for Egyptian Agriculture, 1913-1955*, Institute of National Planning, Cairo, Memo No. 259, December 1962, pp. 4-8. (Noted in Donald C. Mead, *Growth and Structural Change in the Egyptian Economy*, Irwin, 1967, pp. 64-65.)

[20] For example, as part of a complex programming model of the Mexican economy, the Development Research Center of the World Bank and Mexican economists have accumulated data on the time normally occupied by individual crops in the major regions. (Conversation with Roger Norton, May 21, 1971.)

II. HISTORICAL DEVELOPMENT

It may come as a bit of a surprise to learn that multiple cropping has a long, if not well documented, history. Indeed, such information as we have suggests that the practice was carried out well before the time of Christ. Here we shall review what is known of the early history of multiple cropping and then turn to an examination of more recent developments; 1800 will serve roughly as the dividing point for the two periods.

EARLY HISTORY

Although multiple cropping extends back into history several thousand years, it was by no means a common practice. Rather, it was usually found in the densely populated garden spots of the world—areas blessed with a unique combination of favorable climate and soil. Often irrigation was available.[1] The actual area planted during the early period of multiple cropping is not known, but it was probably quite limited.

Most of the information we have on multiple cropping through early 1800 concerns the nature of crop rotations, some of which are familiar today. Other factors have a remarkably contemporary tone; among them are irrigation, early maturing varieties, and taxation. We shall consider the early experience of five nations in order of the earliest reference to multiple cropping.[2]

Babylon and Egypt

The development of double cropping in Babylon and Egypt closely paralleled the growth of irrigation systems. Two quite different irrigation techniques were utilized: Egypt adopted basin irrigation along the Nile, while

[1] While there is a relatively ample history available on the technological development of irrigation, little is said about its effects on cropping patterns (see, for example, R. J. Forbes, "Irrigation and Drainage," in his *Studies in Ancient Technology,* E. J. Brill, Leiden, 1965, Vol II, pp. 1-79). Semple, in her remarkable review of the ancient development of irrigation in the Mediterranean region, notes the impetus irrigation gave to summer crops—the demand for which was stimulated by population and income growth in big urban centers—but does not explicitly make clear whether these represented second crops (Ellen Churchill Semple, *The Geography of the Mediterranean Region: Its Relation to Ancient History,* Henry Holt & Co., 1931, pp. 433-473).

[2] In addition, multiple cropping was practiced in Campania in southern Italy around the time of Christ. See: K. D. White, *Roman Farming,* Cornell University Press, 1970, pp. 47, 82; *The Natural History of Pliny* (trans. by John Bostock and H. T. Riley), Henry G. Bohn, London, 1856, Vol. IV, Book XVIII, Chp. 29, p. 41, Chp. 52, p. 68; and *The Geography of Strabo* (trans. by Horace Jones), G. P. Putnam's Sons, 1923, Vol. II, Book V/4/3, pp. 435, 437.

Babylon relied on a perennial system in the Tigris-Euphrates River delta.[3] Wilcocks notes that while the Egyptian system was far more impressive than the Babylonian, it was "not nearly so profitable since it only ensured one crop per annum instead of two."[4]

Babylon: Just when perennial irrigation and double cropping began in Babylon is uncertain. One estimate would seem to place the inception of irrigation at 4,000 to 6,000 years ago.[5] Another suggests that when the earliest Babylonian calendar was framed, "Babylonia enjoyed perennial irrigation and the two crops per year which that system of irrigation allows."[6] Pliny, around 77 AD, observed that in Babylon, "they cut the blade twice, and then let the cattle pasture on it a third time."[7] During the period of the Islamic conquest from the 7th to 11th centuries "the arable plains of Dasht Run [in Iran] gave four crops a year under irrigation."[8] Most of the irrigation works were destroyed during the invasion of the Mongols in 1258 and never repaired.

Egypt: It is also not clear when multiple cropping started in Egypt. Basin irrigation originated as early as 3,000 to 5,000 B.C.,[9] but was inadequate for a second crop because of the arid climate and porous soil. However, other irrigation devices such as the shadouf, the Archimedes screw, and the Persian Wheel (saqia) have been used since ancient days to lift water from the Nile to garden plots during the period of low water levels in the spring and summer.[10]

Gompertz indicates that in "very early times," Egypt enjoyed, to a slight extent, a form of perennial irrigation at Memphis and Abydos, which together with an absorbent soil, produced more than one crop a year.[11] He goes on to cite a letter written by Appollonius to a farm manager in about 300 BC:

> The King has ordered us to sow the land twice. As soon as you gather the crops irrigate the soils immediately . . . after irrigation, sow three-months' wheat.[12]

[3] Basin irrigation involved flooding of large areas while the Nile was at its peak. Perennial irrigation utilized canals which ran year-round. See: M. S. Drower "Water-Supply, Irrigation, and Agriculture," in *A History of Technology* (ed. by C. Singer, et. al.), Oxford University Press, London, Vol. I, 1954, pp. 535-554; W. L. Balls, *Egypt of the Egyptians*, Scribners, 1916, Chp. 5; H. E. Hurst, *The Nile*, Constable, London, 1952, Chp. 3; and Hanbury Brown, *Irrigation*, Constable, London, 1920 (3rd ed.), Chp. 2.

[4] William Willcocks, *Irrigation of Mesopotamia*, E. & F. Spoon, London, 1917, pp. xii, 5.

[5] William Willcocks, *Lectures on the Ancient System of Irrigation in Bengal*, University of Calcutta, 1930, pp. 2-3.

[6] Maurice Gompertz, *Corn from Egypt; The Beginning of Agriculture*, Gerald Howe, London, 1927, p. 51. Double cropping was also practiced in Assyria (Drower, *op. cit.*, p. 553).

[7] Pliny, *op. cit.*, Chp. 45, p. 59.

[8] R. O. Whyte, "Evolution of Land Use in South-Western Asia," in *A History of Land Use in Arid Regions* (ed. by Dudley Stamp), UNESCO, Arid Zone Research—XVII, Paris, 1961, p. 102.

[9] Forbes, *op cit.*, p. 75; Semple, *op cit.*, p. 433. Also see Leonard M. Cantor, *A World Geography of Irrigation*, Praeger, 1970, pp. 12-15.

[10] Balls, *op cit.*, pp. 134-135; Hurst, *op. cit.*, pp. 42-45. There are several variations of the spelling of shadouf and saqia.

[11] Gompertz, *op. cit.*, p. 20. Memphis is just south of Cairo; Abydos is about 100 miles northwest of Luxor on the Upper Nile.

[12] *Ibid.*, pp. 65-66.

Multiple cropping may have existed to some extent in the Fayum region, now in the desert southeast of Cairo, early in history. The region was once covered by a large lake which was connected to the Nile and replenished annually during the flood stage. According to some accounts, shortly after 2000 BC a large dam was erected to regulate water flow, creating in effect a year-round resevoir—known as Lake Moeris—which could be used for irrigation.[13] Later, during the reign of Ptolemy I and II (circa 300 to 250 BC), the level of the lake was lowered, baring 450 square miles of highly fertile land which was irrigated by canals.[14] It appears that at least some of the irrigation was perennial in nature, which would have permitted double cropping.[15]

One historian credits Ptolemy II with imposing the system of two crops per year in Egypt.[16] Another account of the Ptolemaic period indicates that:

> The artificially irrigated land in many cases paid higher taxes and this would be possible if perennial irrigation really raised more than one crop. However, the new system was not fully exploited . . .[17]

In summary, then, multiple cropping has an ancient history in Egypt but probably was not extensively used because of the limited availability of water.

India

The earliest known reference to double cropping in India is found in a work known as the *Taittiriya Samhita,* which was written by at least 1000 BC (and may well have been prepared before 3000 BC).[18] It distinctly mentions that two crops were harvested from the same field in the course of a year.[19]

Subsequently, double cropping was mentioned in another Indian work, Kautilya's *Arthasastra,* which was probably written about 300 BC. It is reported that raising of a second crop was sometimes made compulsory as a last resource for taxation.[20] About the same time, Megasthenes referred to the advantage of double crops resulting from irrigation.[21]

[13] Bernard P. Grenfell and Arthur S. Hunt, *Fayum Towns and Their Papyri,* London, 1900, pp. 3-5; Abd El-latif Mohamed Rashwan, "Irrigation and Drainage in Fayum as a Unique System in the UAR," *8th NESA Irrigation Practices Seminar,* Kabul, Afghanistan, 1970, p. 251. There are several different spellings of Moeris and Fayum.

[14] John Ball, *Contributions to the Geography of Egypt,* Cairo, 1939, pp. 212-215. Ball adds that "there subsequently ensued a great extension of agricultural activity in the Faiyum and a large increase in its population" (p. 215).

[15] Based on interpretation of information in: Grenfell and Hunt, *op. cit.,* p. 16; Ball, *op cit.,* p. 217; C. Caton-Thompson and E. W. Gardner, *The Desert Fayum,* London, 1934, p. 145; and R. H. Brown, *The Fayum and Lake Moeris,* London, 1892, p. 96. Basin irrigation was clearly utilized, but by the 1800's many of these systems were converted to perennial irrigation (Brown, p. 96); by 1928 the lands were producing an average of two crops a year (Ball, p. 229).

[16] Jean-Philippe Levy, *The Economic Life of the Ancient World* (trans. by J. G. Biram), University of Chicago Press, 1967, p. 36.

[17] Forbes, *op. cit.,* p. 30.

[18] On the question of the date I am indebted to: Mr. Ranjan Borra of the Orientalia Division of the Library of Congress; and B. B. Chaudhuri, Assistant Librarian, National Library, Government of India, Belvedere, Calcutta.

[19] V, 1, 7, 3. Cited in *Agriculture in Ancient India,* Indian Council of Agricultural Research, New Delhi, 1964, p. 81.

[20] *Ibid.,* p. 82.

[21] Hanbury Brown, *op cit.,* p. 7.

More explicit details were provided by the Greek writer Diodorus, in approximately 50 BC. He indicated that "The larger part of the country is well watered and for this reason yields two crops each year." He noted that India had two rainy seasons; during the summer, plantings included rice, bosporos (a kind of millet), sesame, and millet; during the winter, wheat was grown. According to Diodorus, "in most years the Indians are successful in both crops, and they never lose everything, since the fruit of one or the other sowing comes to maturity."[22]

China

Double cropping has long existed in China. In the north it was built around winter wheat, in the south around rice. One of the first references was provided in *Ch'i Min Yao Chu,* written during the period 530 to 580 AD.[23]

Early rice subsequently had a significant impact in making multiple cropping possible. In 1012 AD, an early maturing rice known as Champa was introduced from Fukien to the lower Yangtze and lower Huai areas and seems to have triggered a revolution in growing practices. It, and other similar varieties, could be planted early in the season, making cultivation of a second crop possible. By the Ming Period (1368-1644) at the latest, other varieties had been developed which could withstand fall cold so well that they were planted in mid-summer after the field was entirely cleared of spring crops or early rice.[24]

Rice double cropping (a second crop of rice as opposed to some other crop) was largely concentrated in the south. Kwangtung Province and the southern portion of Fukien Province were reportedly famous for rice double cropping as early as the Ming period, but as Perkins points out, this does not mean that the area was large.[25]

Farther north, in Hunan, a great effort was made by officials to promote the second crops (most likely crops other than rice) during the 17th and 18th centuries.[26]

Japan

The planting of a second grain crop on rice fields dates back to the 13th century. Wheat or barley was first grown as a "backcrop" in the areas of mild climate around the Kinki (Osaka-Koyto) district. By the second half of the 16th century, the practice had become prevalent in southwest Japan. Farmers would keep the winter crops for home consumption and ship the rice to market for the governing classes.[27]

[22] *Diodorus of Sicily* (trans. by C. H. Oldfather), Harvard University Press, 1935, II, 36, pp. 5, 7.

[23] Based on material provided by Office of the Agricultural Officer, American Consulate General, Hong Kong, September 23, 1970, July 27, 1971.

[24] Ping-ti Ho, "Early Ripening Rice in Chinese History," *The Economic History Review,* December 1956, pp. 200-216.

[25] Dwight H. Perkins, *Agricultural Development in China, 1368-1968,* Aldine, 1969, p. 45 (fn. 14).

[26] *Ibid.,* p. 47.

[27] Takane Matsuo, *Rice Culture in Japan,* Yokendo Ltd., Tokyo, 1955, pp. 2, 37; T. Takase, "Current Status and Historical Development of Rice Culture," in *Theory and Practice of Growing Rice* (ed. by M. Matsubayashi, et al.), Fuji Publishing Co., Tokyo, 1967, p. 10.

Several variants were subsequently introduced. During the Tokugawa period (1600-1868), triple cropping began to be practiced where commercial fertilizers were available, winters not too harsh, and soils sufficiently well drained. In more highly settled areas the demand for vegetables led to plantings before and after the rice crop. Rice double cropping began to be practiced in Kochi prefecture around the middle of the 19th century, but did not begin to become commercially important until about 1890.[28]

RECENT HISTORY

Much more statistical data on multiple cropping began to become available during the 19th and 20th centuries. This was also a period of more widespread application of scientific techniques to production; fertilizer and water control were perhaps the most important. The area of irrigated land in the world, for instance, reportedly expanded five fold from 1800 to 1900.[29]

In this section we continue our review of developments in four of the previously discussed nations, plus one new one (Taiwan), through the pre-World War II period. The countries reviewed were probably the most intensively involved in multiple cropping; in other areas the practice remained limited at best. Yet, there is much from this period which could provide insights for many less developed countries today.

Egypt

Multiple cropping on a commercial scale was introduced in the Nile Delta in the early part of the 19th century by Muhammad Ali. In 1821 work started on the construction of larger and deeper (sayfi) canals in the Delta so that irrigation could take place at the low stage of the Nile.[30] Two examples of land use in the Delta reported in 1824 indicate a cropping index of 125. A subsequent survey of a 1000-acre estate in the Delta in the early 1840's revealed that 50% of the land was planted to three crops and 30% with two (producing an overall index of 230).[31] Perennial irrigation made it possible to produce commercial summer crops; cotton was particularly important.

Soon, however, Ali was finding it exceedingly difficult and expensive to get the canals deepened and cleared. An alternative was to raise the incoming water level through the construction of dams or barrages. The apex of the Delta, where the Nile branched, provided a prime location. After several false starts, beginning in 1833, the construction of barrages on both the Rosetta and Damietta branches finally got underway in 1843. (The two barrages were located so that they each represented wings of an overall unit.) Work was

[28] Thomas C. Smith, *The Agrarian Origins of Modern Japan*, Stanford University Press, 1969, p. 94; Matsuo, *op. cit.*, pp. 2, 37.

[29] N. D. Gulhati, "Worldwide View of Irrigation Developments," *Journal of the Irrigation and Drainage Division; Proceedings of the American Society of Civil Engineers*, September 1958 (Vol. 84, No. IR3), paper 1751, p. 3. Gulhati provides a brief survey of the development of irrigation systems in each of 59 nations in his report, *Irrigation in the World: A Global View*, International Commission on Irrigation and Drainage, New Delhi, 1955, 130 pp.

[30] Helen A. B. Rivlin, *The Agricultural Policy of Muhammad Ali in Egypt*, Harvard University Press, 1961, p. 245.

[31] E. R. J. Owen, *Cotton and the Egyptian Economy, 1820-1914*, Oxford University Press, 1969, pp. 12, 49.

largely completed in 1861. The Rosetta Barrage was tested for the first time in 1863 and partially failed. Further engineering problems followed.[32]

Egypt fell under British rule in 1882, and emphasis was quickly placed on improving and extending the perennial irrigation system. The Delta Barrage was restored and other improvements made.[33] These developments made possible a sharp increase in multiple cropping. The cropping index expanded from 100.4 in 1879 to 138.2 in 1899.[34] With the completion of the first Aswan Dam in Upper Egypt in 1902, the index continued to increase through the first half of the 1900's (see Table 1). Multiple cropping was, however, still largely confined to the Delta: of nearly 2.4 million acres reported double cropped in 1911-12, over 1.6 million was in the Delta and over 0.7 million in Upper Egypt; the cropping index in the Delta was 153, while that for Upper Egypt was 133.[35]

The expansion in irrigation was generally not matched by improvements in drainage. Further, when water is available by gravity, overwatering is likely to occur. The combination of saltiness and a high water table has limited yields.[36]

While the cropping pattern normally involved growing only a second crop, in some areas a third crop known as the Nili was raised; it was sown in July and

Table 1.—Multiple Cropped Area and Indexes, Egypt

Year or Season	Multiple Cropped Area	Index
	(1,000 acres)	
1879	20	100.4
1899	2,019	138.2
1906/7	2,345	141.8
1916/17	2,500	145.7
1926/27	3,235	156.2
1936/37	3,194	158.3
1946/47	3,535	159.1

Source:—Computed from data provided in Donald C. Mead, *Growth and Structural Change in the Egyptian Economy,* Irwin, 1967, pp. 2, 4, 64.

[32] W. Willcocks and J. I. Craig, *Egyptian Irrigation,* E & F Spoon Ltd., London, 1913 (3rd edition), Vol. II, pp. 633-634; Rivlin, *op cit.,* pp. 233-237. Also see R. H. Brown, *The Delta Barrage of Lower Egypt,* Cairo, 1902, 80 pp. (illustrated), and Robert L. Tignor, "British Agricultural and Hydraulic Policy in Egypt, 1882-1892," *Agricultural History,* April 1963, pp. 63-72.

[33] *Ibid.*

[34] Donald C. Mead, *Growth and Structural Change in the Egyptian Economy,* Irwin, 1967, p. 2.

[35] Willcocks and Craig, *op. cit.,* p. 770.

[36] Marion Clawson, H. H. Landsberg, and L. T. Alexander, *The Agricultural Potential of the Middle East,* American Elsevier Co., 1971, p. 27. Also see Willcocks and Craig, *op cit.,* Chp. VIII, and Hanbury Brown, *op. cit.,* pp. 251-253.

August and harvested in the fall. In most rotations, however, at least one of the three periods was kept fallow, so that the general result was double cropping at best. One common rotation was as follows:

Season	*Year 1*	*Year 2*
Winter	birsim (clover)	beans or wheat
Summer	cotton	fallow
Nili	fallow	maize or fallow

Additional winter crops included barley; sesame, maize, rice, and sugar might also be grown in the summer.[37]

India

By the late 1800's and early 1900's multiple cropping was widely practiced in India. Data for 61 districts, representing about one third of India's total population in 1951, suggest the following multiple cropped areas and indexes:[38]

Year	*Area (million acres)*	*Cropping Index*
1891	9.9	111.0
1921	10.9	111.7

Multiple cropping appears to have been heavily concentrated in the Ganges River Valley. Statistics for scattered towns in the Upper Valley are summarized in Table 2. The seven indexes reported ranged from 112 to 135 by the early 1900's. Indexes for the major regions in the valley in 1931 are reported in Table 3. The indexes were highest in the Middle Valley (Bihar), ranging from 120 to 130, next highest in the Upper Valley (Uttar Pradesh), and lowest in West Bengal.

According to Ganguli, much of the multiple cropping carried out in the Ganges Valley in the 1930's was of a rather low order. He indicated that double cropping usually was "a sign of intensive subsistence farming and improvident husbandry." The process was used to produce the cheaper varieties of rabi and kharif foodgrains which provided the subsistence for the cultivator and his family. He acknowledged that sometimes "double cropping is practiced on highly manured land near the village sites and is guided by intelligent methods of agriculture;" he also noted that in the deltaic portions of the Plain (now partly in East Pakistan) the annual rise of the river left a fertilizing deposit of silt so that double cropping did not mean "predatory cultivation." But for the most part, he indicated that double cropping "usually implies imperfect tillage and wasteful cultivation."[39]

[37] Owen, *op. cit.*, pp. 7-9, 252-253.

[38] V. Nath, "Population, Natural Resources, and Economic Development in India," in *Geography and a Crowding World* (ed. by Wilbur Zelinsky, et al.), Oxford University Press, 1970, pp. 397, 399. (Based on *Census of India 1951, Vol. I, Part 1/B, Appendices to the Census Report*, New Delhi, pp. 48-49.)

[39] Birendranath Ganguli, *Trends of Agriculture and Population in the Ganges Valley*, Methuen, London, 1938, pp. xiii, 57.

Table 2.—Multiple Cropping Indexes in Upper Ganges Valley[1] India, Late 1800's and Early 1900's

Region and Town	Late 1800's		Early 1900's	
	Period or Year	Index[2]	Period or Year	Index[2]
East				
Benares	1886-1896	118.8	1894/5-1904/5	125.0
Jaunpur	1886-1896	122.4	1902-1906	128.0
Central				
Crawnpore	1870	104.9	1909	114.5
Sultanpur	1864	104.5	1902	135.4
Allahabad	1873	105.7	1902/3-1907/8	123.3
Fatehpur	1870	108.7	1904	112.0
West				
Meerut	1860	104.5	1902	121.0

[1] Patna to New Delhi.

[2] Double cropped area as percent ot total cultivated area; converted to index by adding 100.

Source:—Birendranath Ganguli, *Trends in Agriculture and Population in the Ganges Valley,* Methuen & Co., London, 1938, pp. 55-56.

Table 3.—Multiple Cropping Indexes in the Ganges Valley, India, 1931

Region	Index[1]
Upper Ganges Valley (Uttar Pradesh)	
East	120.3
Central	116.8
West	113.8
Middle (Bihar)	
North	130.2
South	120.2
Delta (Bengal)[2]	
West	108.0

[1] Double cropped area as percent of total cultivated area; converted to index by adding 100.

[2] Excluding areas now in East Pakistan: Central Bengal, 127; and Eastern Active Delta, 133.8

Source:—Birendranath Ganguli, *Trends in Agriculture and Population in the Ganges Valley,* Methuen & Co., London, 1938, pp. 55-56.

Ganguli made a special point of the fact that the economic importance of double cropping should be judged not only by the area involved but also by the value of the crops raised. In the category of valuable crops he included tobacco, chillies, wheat, and barley. In the less valuable category he included

catch crops like khesari, peas, kuthi, gram, and linseed.[40] The precise listing varied by season and locality.[41]

China

Perspective on multiple cropping in China during the early 1900's is provided by two remarkable Americans, F. H. King and John Lossing Buck. King made an extended trip through China in 1909 and provides numerous first hand observations of multiple cropping. But the nature of his travels did not provide much quantitative data.[42]

Statistics, however, were supplied in abundance by Buck, in two separate studies. The first was a survey of 2,866 farms in 17 localities in 7 provinces over the 1921-1925 period. The provinces were located in north and east central China. The overall multiple cropping index was *147* and ranged from a low of 100 in one locality in Shansi to a high of 197 in Kiangsu. Buck observed that length of growing season and feasible crop combinations, not farm size, were the determining factors in the amount of double cropping.[43]

A subsequent study was even more extensive. It was conducted in 1929-1933 and covered 16,456 farms in 164 localities in 22 provinces. The overall multiple cropping index was slightly higher, *149*. Buck broke the indexes down into two main sections: the northern was designated the wheat region and had an index of 127; the southern was termed the rice region and had an index of 166. Within each region there were a number of crop areas: in the north their indexes ranged from 107 to 139; in the south the range was 152 to 176. The latter figure was obtained in the "double cropping rice area" which included Kwangtung and parts of Kwangsi, Kiangsi, and Fukien.[44]

As in his earlier study, Buck observed that the amount of double cropping was primarily influenced by climatic factors and not size of farm. He stated that in areas where the winter crop was of secondary importance, the amount of double cropping was influenced by the need for food and freedom from rent payment on winter crops. Buck also noted that triple cropping occurred in a few localities in all the areas of the rice region but one.[45] (King also noted triple and quadruple cropping in southern China.[46])

[40] *Ibid.*, p. 162.

[41] This produced several different patterns even within the Ganges Valley. In the Upper Ganges, double cropping consisted of raising a cheap rabi crop to supplement the main kharif harvest. In the Middle Ganges, where there were three seasons (bhadoi, aghani, and rabi), only rabi crops grown directly after the bhadoi harvest were valuable; those raised after the aghani harvest were only cheap cold weather catch crops. In the moribund Delta, where soil and water were poor, the principal crop was the aghani and the rabi area was insignificant; where conditions were more favorable there was more rabi. In the active Delta, both the bhadoi and aghani (aman) crops were valuable while the rabi was not. (*Ibid.*, p. 255.)

[42] F. H. King, *Farmers of Forty Centuries, or Permanent Agriculture in China, Korea, and Japan,* Harcourt Brace & Co., 1911, pp. 19, 87. (King was Chief of the Division of Soil Management, USDA.)

[43] John Lossing Buck, *Chinese Farm Economy,* University of Chicago Press, 1930, pp. 190-197.

[44] John Lossing Buck, *Land Utilization in China,* University of Nanking, 1937, p. 216.

[45] *Ibid.*

[46] King, *op cit.*, p. 87.

Generally the second crop was other than rice. Perkins reports the following breakdown of double cropped area in 1931-37:

Winter Wheat	45%
Barley	14
Rapeseed	13
Pulses	11
Rice	10
Other	7

While the practice of growing two crops of rice had been known for centuries, it was not widely used. Even by the 1930's it was largely confined to the provinces of Kwangtung, Kwangsi, and southern Fukien; in fact, nearly 80% of the area double cropped to rice was found in these three provinces.[47]

Thus the two main double cropping patterns were: (a) rice followed by barley, rapeseed, or pulses in the south; and (b) winter wheat followed by coarse grains and other crops in the north.

Japan

Multiple cropping in Japan was encouraged by two developments in the 19th and early 20th centuries. One was the expansion in availability of commercial fertilizers. The other was the improvement of drainage technology which allowed upland crops to be grown in winter or spring.[48]

Oddly, these improvements are not reflected in statistics on the proportion of paddy fields planted to second crops. During the period from 1903 to 1922, the proportion fluctuated from 29 to 31% with no clear trend.[49] One possibility may be that the statistics refer only to area cropped more than once; this would not reflect the increase in area cropped more than twice.[50] Another contributing factor may have been the concurrent expansion in single cropping area in the northern part of the country.[51]

Following 1922, the proportion of paddy double cropped dropped to a low of 26.6% in 1929 and 1930, and then increased through 1940. The drop through the 1920's may well represent (a) the more general stagnation of Japanese agriculture during this period,[52] and (b) the continued increase in the single cropping areas. Summary data are presented in Table 4.[53]

If the exact indexes are uncertain, other developments are clearer. One was a gradual movement of double cropping northward. Also, land utilization was

[47] Perkins, *op cit.*, pp. 43, 46.

[48] James I. Nakamura, *Agricultural Production and the Economic Development of Japan, 1873-1922*, Princeton University Press, 1966, pp. 39-50; Smith, *op cit.*, p. 94.

[49] Nakamura, *op. cit.*, p. 42.

[50] *Ibid.*, p. 50; letter from Nakamura, East Asian Institute, Columbia University, December 11, 1970.

[51] Hayami notes that the paddy crop area in two such regions expanded as follows from 1900 to 1920; Hokkaido + 181,000 acres; Tohoku + 83,000 (Letter from Yujiro Hayami, Faculty of Economics, Tokyo Metropolitan University, December 22, 1970).

[52] See Yujiro Hayami and V. W. Ruttan, "Korean Rice, Taiwan Rice, and Japanese Agricultural Stagnation: An Economic Consequence of Colonialism," *Quarterly Journal of Economics*, November 1970, pp. 563-573.

[53] The regional variation in cropping intensities for paddy and upland fields in 1937 is depicted in G. T. Trewartha, *Japan, A Geography*, University of Wisconsin Press, 1945, pp. 205, 206.

intensified as urbanization progressed and the demand for food increased, as transportation improved, and as labor-saving innovations were introduced during periods of peak needs.[54]

Taiwan

A rather complete historical record of cropping indexes is available for Taiwan during the 20th century. They are presented in Table 5. There was relatively little change in the indexes until the 1930's. A drop occurred during World War II, followed by a very sharp post-war increase.[55] According to Lee, it was possible to expand the area of newly reclaimed land through 1935; however, after 1940 population pressure grew rapidly and there was increasing need for multiple cropping.[56]

Table 4.—Proportion of Paddy Land Multiple Cropped, Japan (excluding green manure crops)

Period	Average (Percent)
1903 - 1905	30.4
1906 - 1910	30.2
1911 - 1915	30.8
1916 - 1920	30.7
1921 - 1925	28.3
1926 - 1930	26.8
1931 - 1935	27.9
1936 - 1940	31.0

Source:—Calculated from data provided in Nobufumi Kayo (ed.), *Nihon Nogyo Kiso Tokei,* Tokyo, 1958, p. 72. Reference provided by James I. Nakamura, East Asian Institute, Columbia University.

Table 5.—Multiple Cropping Indexes, Taiwan

Period	Average Index
1911 - 1915	116
1916 - 1920	118
1921 - 1925	121
1926 - 1930	122
1931 - 1935	132
1936 - 1940	133
1941 - 1945	131
1946 - 1950	151
1951 - 1955	172
1956 - 1960	180

Source:—T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 11.

[54] Nakamura, *op cit.*, p. 49; Matsuo, *op cit.* (1955), p. 37.

[55] Other sources indicate that the index was particularly low in 1945 when it dropped to 106 or 111 (Yhi-Min Ho, *Agricultural Development of Taiwan, 1903-1960,* Vanderbilt University Press, 1966, p. 50; *Taiwan Agricultural Yearbook, 1969 Edition,* Department of Agriculture and Forestry, June 1969, p. 21).

[56] T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 9.

The development of cropping rotations occurred as follows. From 1910 to 1920, multiple cropping was largely limited to two crops. During the 1920-40 period, triple cropping of paddy land became more important; this involved following double cropping of rice with a winter crop. The concept of using other crops as the third unit of the rotation occurred about as follows: wheat, 1922; corn, 1931; flax, 1936; tobacco, 1942; soybeans, 1957; rapeseed, 1959; and asparagus, 1960.[57] Quadruple cropping of paddy land, involving a summer crop between the first and second rice crops, emerged in the 1940-60 period. On non-paddy lands, cropping was largely limited to two crops (often including sweet potato) until the 1940-60 period when triple cropping became more common.

* * *

Thus we see that multiple cropping, when viewed in historical terms, has emerged as a result of a multitude of factors. These are worthy of further examination. We might sort them out into two broad categories: biological-physical, and economic-social. Each will provide the basis of the two following chapters.

[57] Letter from C. L. Luh, Plant Industry Division, Joint Commission on Rural Reconstruction, Taipei, August 8, 1970.

III. BIOLOGICAL AND PHYSICAL ASPECTS

Multiple cropping is not so much a technology itself as it is the product of a number of interacting technologies. Certain key ingredients such as irrigation and early-ripening varieties have long been available in certain regions of the world. But for many less developed nations today, these factors are relatively new or are present in new form. The fact that appropriate technologies are more widely available means that the potential for the expansion of multiple cropping is enhanced.

There is, however, a great gulf between potential and reality. In this chapter we shall review some of the biological and physical factors which may influence the gap. They include the overriding influence of climate, the nature of the needed biological and physical inputs, cropping sequences and yields, and the critical problem of timing. The treatment of these matters in this chapter is—as biologists will quickly recognize—more suggestive than comprehensive. Some of the ecological considerations are subsequently noted in Chapter VI.

INFLUENCE OF CLIMATE AND SOIL

Multiple cropping is carried out under a wide variety of climatic conditions and soil types, making it difficult to generalize about their influence on multiple cropping. Yet a few observations may be made, particularly in the case of climate.

Climate

Multiple cropping is found largely in a belt between 10° south and 40° north of the equator. Three basic climatic zones are involved: the cool temperate; the warm-temperate sub tropical; and the tropical (which in turn can be differentiated into the humid and subhumid).[1] Climatic conditions in the countries involved normally allow cultivation year-round or over a long growing season. Given adequate heat, the multiple cropping pattern followed within this region is heavily dependent on the availability of water, either through rainfall or irrigation.

The distribution of rainfall varies somewhat between and within nations. Some Asian nations experience only one monsoon a year, while others such as Ceylon may have two. In West Malaysia there are two dry periods: from June to August, and December to February. In large countries like India, several situations prevail: there is only a summer rain in the vast central portion of the nation, while two rainy periods (though not of equal intensity) are found in

[1] See "Water and Land," *The World Food Problem,* The White House, Vol. II, May 1967, pp. 419-420.

the southernmost and northernmost portions. Thus one part of the country during the wet season might well have considerably more rain than another.

Multiple cropping in Asia is often built around a summer (or wet season) crop of rice. This rice is grown in (a) irrigated or rainfed paddies where the water can be impounded, or (b) under upland conditions where water is not impounded.[2] On paddy land, the first or summer crop is nearly always rice. During the winter (or dry season) this land may be planted again to rice, but is often devoted to another crop. Rice requires a great deal of water and generally can be grown only when irrigation is available. An exception is provided in the Sino-Japanese part of the rice belt, where winter rainfall is considerably heavier than in regions farther south; and since the winters are cooler, there is less evaporation.[3]

In other regions, rice is less important as a base for the multiple cropping rotations. Depending on climatic conditions, various grains, vegetables, or pulses may be grown in the wet season. Where water is particularly short in the dry season, certain grains such as sorghums or millet may be particularly important. With the recent expansion of pumpsets, the variety of crops that can be grown in the dry season will be expanded.

There are, of course, many possible combinations for varying weather conditions. We shall encounter at least some of them in the following pages.

Soil

The soil requirements for multiple cropping are basically no different than for other forms of intensive crop production. In each case, a deep fertile soil with good structure and texture is usually desired.[4] These features can be modified to some extent by cultural practices, most notably by the addition of organic or chemical fertilizer.

Soils are most apt to present a problem for multiple cropping in the wet equatorial regions. In the tropical rain forests of these areas, soils are often relatively infertile due to leaching and contain limited organic matter. The clearing and cultivation of certain soils containing laterite can lead to hardening of the laterite and even to the formation of a rocklike substance.[5]

Yet there are exceptions even in humid tropical regions. Younger alluvial soils formed by deposits along streams and rivers or by volcanic ash may be quite suitable for permanent agriculture and multiple cropping. The area

[2] This definition draws from S. C. Hsieh and V. W. Ruttan, "Environmental, Technological, and Institutional Factors in the Growth of Rice Production: Philippines, Thailand, and Taiwan," *Food Research Institute Studies,* 1967 (Vol. VII, No. 3), p. 313, fn. 2.

[3] V. D. Wickizer and M. K. Bennett, *The Rice Economy of Monsoon Asia,* Food Research Institute, Stanford, 1941, pp. 43, 45.

[4] Rice grown under flooded conditions, however, can tolerate poor soil structure (see fn. 34).

[5] Lateritic soils are briefly discussed in "Water and Land," *op. cit.*, pp. 415-416, and by Charles E. Kellogg and Arnold C. Orvedal in "Potentially Arable Soils of the World and Critical Measures for Their Use," *Advances in Agronomy,* Vol. 21, 1969, p. 150. Detailed reviews are presented in: S. Sivarajasingham, et al., "Laterite," *Advances in Agronomy,* Vol. 14, 1962, pp. 1-60; and Lyle T. Alexander and John G. Cady, *Genesis and Hardening of Laterite in Soils,* U.S. Department of Agriculture, Technical Bulletin No. 1282, December 1962, 90 pp. (These references were kindly suggested by Dr. Matthew Drosdoff of Cornell University.)

involved, however, is not likely to be great (except in Java where volcanic ash has been spread over most of the country).

MAJOR PRODUCTION INPUTS

Throughout history, multiple cropping has been practiced in the more advanced and/or more favored agricultural areas. In some of these regions it attained a relatively high degree of development. But the area involved was not great and the full potential not reached. More widespread adoption has had to await the development of an increasingly scientific agriculture. The most significant technological contributions include improved varieties, water control, fertilizer, insect and disease control, and post-harvest technology. Mechanization may become increasingly important in the future (and will be discussed in a later section of this chapter).

Varieties

Varietal characteristics play a key role in making multiple cropping possible and in determining cropping systems.

One of the most important factors is time of ripening. The shorter the growing season required by individual crops, the greater the possibility of raising an additional crop within the available growing season. Thus increased availability of early-maturing varieties is generally associated with an increase of multiple cropping.[6]

Perhaps the earliest example of this occurred in Mainland China. Ho suggests that early maturing rice varieties helped bring about the development of a double cropping system in China as early as the year 1000.[7] Early ripening is now a characteristic of most grains in China.[8]

The development of the shorter season ponlai rice varieties in Taiwan in the early 1920's helped make it possible to (1) move from double to quadruple cropping in Central Taiwan by adding a winter catch crop and a summer crop between the first and second rice crops, and (2) add a third crop in Southern Taiwan.[9]

It is also important that varieties grown in a multiple cropping rotation mature in a relatively set period of time. For this reason, photoperiod-insensitive varieties are desired. They tend to mature in a relatively fixed number of days after planting, and are less influenced in this respect by daylength than are photoperiod-sensitive varieties.

[6] An interesting exception is provided by some of the new high-yielding wheat varieties in West Pakistan. While they mature more quickly than traditional varieties, they may have led to a decline in multiple cropping. The reason is that they are so profitable and adaptable, that they have evidently been substituted for two minor crops during the winter season. (Letter from Jerry B. Eckert, The Ford Foundation, Lahore, March 1, 1971.)

[7] Ping-ti Ho, "Early Ripening Rice in Chinese History," *The Economic History Review*, December 1956, pp. 200-216.

[8] Dwight Perkins, *Agricultural Development in China, 1368-1968*, Aldine, 1969, p. 41.

[9] Yhi-Min Ho, *Agricultural Development of Taiwan, 1930-1960*, Vanderbilt University Press, 1966, pp. 97, 99.

Further desired characteristics for grain varieties are: yield rather than vegetative responsiveness to fertilizer, short strong stems that limit lodging, as much natural insect and disease resistance as possible, and consumer acceptance. Those varieties which are to be raised in nonirrigated regions also may need to be drought resistant.

Recently, wheat and rice varieties have been developed which have many of these characteristics. They are highly responsive to improved agricultural practices and this has led to their categorization as high-yielding varieties.[10] The fact that they also tend to be photoperiod-insensitive has particular meaning for expanded multiple cropping.

Water Control

Since few areas experience rainfall which is both adequate and properly distributed for multiple cropping, the practice is often closely associated with the availability of irrigation water and/or drainage programs. FAO data suggest that for eight Asian nations in 1962 the cropping index averaged 112 on irrigated land and 97 on nonirrigated land.[11] Irrigation may be used to (1) increase the supply of water during the present single crop growing season, and/or (2) extended the growing season over different parts of the year. While irrigation during these periods helps make multiple cropping possible, the relationship works both ways; multiple cropping may be necessary to justify the expense of putting in irrigation.

Throughout history, the areas which have practiced at least some degree of multiple cropping have generally been leaders in the early development of irrigation: Egypt, Mesopotamia, India, and Mainland China. The major exception was Campania in Italy which had exceptional soil conditions. Ho states that the provision of irrigation was the critical factor in contributing to the rise in the multiple cropping index in Taiwan from 1901 to 1943 (the results of a statistical study for the period show a r^2 of .80).[12]

The current extent of irrigation in the less developed nations is presented in Table 6. The roster of nations listed includes nearly all of those which practice multiple cropping to any significant extent. Of the 20 listed, the only ones where to my knowledge, multiple cropping is not of some importance are Turkey, Argentina, Chile, Peru, Sudan,[13] and Madagascar.

[10] I have documented the development and spread of these varieties in my report on *Imports and Plantings of High-Yielding Varieties of Wheat and Rice in The Less Developed Nations,* U.S. Department of Agriculture, Foreign Economic Development Service (in cooperation with U.S. Agency for International Development), Report No. 8, January 1971, 43 pp. Also see D. S. Athwal, "Semidwarf Rice and Wheat in Global Food Needs," *The Quarterly Review of Biology,* March 1971 (Vol. 46, No. 1), pp. 1-34.

[11] *Indicative World Plan, Provisional Regional Study No. 4, Asia and the Far East,* Vol. II, 1968, pp. 42-50. In several countries the index was reportedly higher on nonirrigated land; in these cases the nonirrigated land may receive adequate natural rainfall whereas the irrigation is provided more marginal areas.

[12] Ho, *op. cit.* (1966), p. 96.

[13] The Sudan, located just south of Egypt on the Nile, might seem a likely prospect for multiple cropping. The climate, however severely limits this potential and only in scattered cases (and then most usually in the relatively densely settled Northern Province) is the cropping intensity greater than 100 on irrigated land. (Letter from D. S. Thornton, Department of Agricultural Economics and Management, University of Reading, April 16,

Table 6.—Area of Irrigated Land in Less Developed Nations[1]

Rank	Country	Year	Area
			(million acres)
1	Mainland China	1960	182.9
2	India	1967	68.0
3	Pakistan	1965	29.8
4	Iran	1960	11.5
5	Iraq	1963	9.1
6	Indonesia	1961	9.1
7	Mexico	1960	8.7
	(Japan)	(1968)	(7.8)
9	Egypt (UAR)	1968	6.9
9	Thailand	1968	4.4
10	Turkey	1967	3.8
11	Argentina	1957	3.7
12	Chile	1964/65	2.7
13	Peru	1966	2.7
14	Philippines[2]	1966	2.4
15	South Korea[2]	1968	1.9
16	Burma	1965	1.9
17	Sudan	1967	1.8
18	Madagascar	1966	1.5
19	South Vietnam[3]	1968	1.5
20	Taiwan	1968	1.4

[1] Irrigated arable land and land under permanent crops.
[2] Rice crop only.
[3] Excludes several provinces.

Source:—*Production Yearbook, 1969,* FAO, 1970, pp. 9-10.

The quality of irrigation varies extremely widely and much of the land listed as irrigated is undoubtedly very inadequately covered. In some, perhaps many, parts of the world, irrigation systems were not designed to maximize output per acre but rather to spread the available supply as widely as possible in order to reduce the possibility of crop failure.[14] Quality is particularly apt to depend on whether canal or well irrigation is utilized.

Canal water is normally obtained from streams or rivers and hence the quantity available is largely dependent on seasonal flows. Thus when canal water is needed most in the dry season, it is likely to be (depending on reservoir capacity, if any) in the scarcest supply.[15] This has led to the rationing of water in the winter in West Pakistan.[16]

1971; Arthur Gaitskell, *Gezira: A Story of Development in the Sudan,* Faber & Faber, London, 1959 (esp. p. 121); J. D. Tothill, *Agriculture in the Sudan,* Oxford University Press, 1948.)

[14] See John W. Mellor, "The Evolution of Rural Development Policy" in *Developing Rural India: Plan and Practice* (by Mellor, et al.), Cornell University Press, 1968, pp. 42-44.

[15] The seasonal flow of rivers in arid regions is subject to greater annual fluctuations than in more humid regions. The maximum discharge of the Nile in the summer is about twenty times that in the winter. (David Grigg, *The Harsh Lands: A Study in Agricultural Development,* Macmillan, London, 1970, p. 179.)

[16] Sayed Mushtaq Hussain, "Price Incentives for the Production of High-Yielding Mexican Varieties of Wheat," *Pakistan Development Review,* Winter 1970, p. 452.

> Many of India's large irrigation schemes do not provide the type of irrigation service required for . . . systematic multiple cropping. Most are primarily power stations, and water is released for irrigation during the *kharif* [monsoon] season mainly as a protective measure against poor rainfall. In most years only a limited area receives water during the *rabi* [dry season].[17]

In Maharastra State in India, canals and tanks (reservoirs) reportedly supply water on a perennial basis to only a small proportion (0-15%) of the area commanded by these works.[18] Other problems with canal water center about timing: getting what water there is to the right field at precisely the right time during the growing season.

Well water is less subject to seasonal variations in supply and can more nearly be provided when needed, but still the supply may be limited and the cost considerably higher. Electric or fuel powered tubewells can, where groundwater supplies are adequate, provide a large supply. They have been widely adopted in northern India and West Pakistan. Yet such wells may be even more expensive to operate and economically-sized units may be too large for the small farmer. Tubewells, however, may be used to supplement more traditional sources of irrigation water. And in some cases privately pumped water is sold to small growers.[19]

There is clear evidence that in some regions where tubewell irrigation is practiced, the cropping index is higher than in canal irrigated regions.

– India. A study of the Punjab in India places the multiple cropping index in well-irrigated regions in 1968/69 at 150 as opposed to 125 in canal-irrigated sections. Moreover, it projected that by 1983/84, the index will increase to 180 in the well sections while it will remain the same (at 125) in the canal regions.[20]

– West Pakistan. In 1963/64, the cropping intensity of tubewell farmers in three districts averaged about 138 as opposed to 107 for non-tubewell farmers.[21] A subsequent survey in 1967 revealed an average ratio of 135 for tubewell farmers as compared to 90 for non-tubewell farmers. The principal problem with canal irrigation was reported to be the unreliability of supply.[22]

[17] P. K. Mukherjee and B. Lockwood, "High-Yielding Varieties Programme in India–Assessment," presented at the 28th International Congress of Orientalists, Canberra, January 1971, p. 26.

[18] Martin H. Billings and Arjan Singh, "Agriculture and Technological Change in Maharashtra (1968-1984)," US/AID, New Delhi (no date, but received March 1971), pp. 56, 58.

[19] I. R. Wills, "The Implications of the Green Revolution for Future Production Income and Employment in Agriculture in Western Uttar Pradesh, India," University of Illinois, Ph.D. dissertation, 1970; abstract in *Dissertation Abstracts International*, March 1971, p. 4359A.

[20] Martin H. Billings and Arjan Singh, "Farm Mechanization and the Green Revolution, 1964-1984, The Punjab Case," US/AID, New Delhi, April 22, 1970, p. 48.

[21] Ghulam Mohammad, "Private Tubewell Development and the Cropping Patterns in West Pakistan," *The Pakistan Development Review*, Spring 1965, pp. 25,26.

[22] Hiromitsu Kaneda and Mohammed Ghaffar, "Output Effects of Tubewells on the Agriculture of the Punjab: Some Empirical Results," *Pakistan Development Review*, Spring 1970, pp. 71-72.

The provision of irrigation water is, however, only one aspect of water control. Drainage is the other major factor. Adequate drainage is needed in the short run in order that proper aeration is provided; this is particularly important for crops like corn and vegetables. Over the longer run, proper drainage is needed to avoid chronic waterlogging of the soil or the buildup of salinization. These problems are well summarized by Walton:

> With apparently unlimited supplies of water too much is applied to the fields and under conditions of poor drainage the ground-water table rises and formerly cultivated land is replaced by lakes and marsh, as in parts of the Nile Delta and in the Sind.
>
> Waterlogging is often accompanied by an increase of salts in the soils to levels which even the most salt-tolerant crops cannot withstand.[23]

The problems are most common with canal irrigation. The increased use of tubewells has made significant contributions toward overcoming them in large areas of West Pakistan and northern India.[24]

Clearly, effective water control involves an integrated program of irrigation and drainage.

Fertilization Needs

Except for regions where annual flooding takes place, fertilization is usually essential if multiple cropping is to be carried out over any extended period. The amount needed will vary with the intensity of the rotation and the type of crop grown. Regular inclusion of a legume crop, especially if it is plowed in, may actually restore nitrogen.

Over time, fertility has been restored to the soil in many ways: through annual flooding, application of human or animal manure, or the use of dried fish or oil cakes. Some of these techniques can still be used, but the trend in the more developed regions is toward chemical fertilizers.

Little information is available on the nutritional needs of individual crops in a multiple cropping rotation. In India it has been suggested that in double cropping, one crop should be deep rooted and the other more shallow rooted so that different layers of the soils can be tapped for nutrients. It has also been noted that wheat and rice have a very complementary effect in the utilization of different forms of soil phosphorus.[25] Recent research in India has also indicated that the new high-yielding varieties used in many rotations have a

[23] K. Walton, *The Arid Zones,* Hutchinson University Library, London, 1969, pp. 130-131. Also see Grigg, *op cit.,* p. 183, and the section on Egypt in Chapter V of this report.

[24] See Leonard M. Cantor, *A World Geography of Irrigation,* Praeger, 1970, pp. 125-127.

[25] M. S. Swaminathan and S. S. Bains, "Latest Technology for Multiple Cropping—Principles, Practices and Problems," *The National Seminar on Multiple Cropping,* New Delhi, May 1970, pp. 68-69.

much higher requirement for micro-nutrients than do the traditional varieties.[26]

Much more needs to be known about the interrelationships between various rotations and fertilizer needs.

Insect, Disease, and Weed Control

Multiple cropping provides a longer period of plant life which in turn is likely to lead to increased insect and disease problems. Moreover, some of the newer high-yielding varieties may be more susceptible to local diseases or insects than native varieties. In India, where multiple cropping has increased, it is stated that "some diseases which were hitherto either unknown or only of local importance have assumed epidemic proportions."[27] Reportedly in multiple cropping areas in Egypt, "army worms move from corn to sorghum and back again with the change in crops."[28]

There are four possible solutions: (1) step up chemical control measures, (2) breed for natural plant resistance, (3) attempt biological control, or (4) arrange the rotations so that no two crops sharing the same pests and diseases are grown in sequence. The first three have particular difficulties and limitations: chemical control can be expensive and cause ecological problems; breeding and biological control take considerable time to develop. The fourth method, the proper arrangement of rotations, is a logical starting point but there may be limitations as to how much can be immediately accomplished.

Weed control, according to Bradfield, takes more time than any other operation in multiple cropping.[29] Reduction of the fallow can shorten the period during which weeds grow unimpeded. On the other hand, in the irrigated rice paddy areas in southeast Asia, the traditional fallow during the dry season helps kill off aquatic weeds. Similarly, dryland weeds are killed by drowning in the wet stage. Thus a change in practice may increase the need to make use of chemical herbicides.[30] But as Bradfield has noted, their use in a highly diversified cropping system becomes very complicated, especially if interplanting is practiced.[31]

Post-Harvest Technology

Multiple cropping means that increased output of traditional crops or supplies of new crops will be available. This may increase the load on existing

[26] N. S. Randhawa and C. L. Arora, "Micronutrient Problems of Multiple Cropping in India," *Indian Farming,* October 1970, p. 19.

[27] S. P. Raychaudhuri, "Diseases of Rice and Wheat: Problems in an Intensive Programme," *Indian Farming,* October 1970, pp. 33, 35.

[28] Max F. Millikan and David Hapgood, *No Easy Harvest: The Dilemma of Agriculture in Underdeveloped Countries,* Little, Brown & Co., 1967, p. 49. Other examples are noted by Swaminathan and Bains, *op cit.*, pp. 66, 67.

[29] Richard Bradfield, "Time is Important in Multiple Cropping," International Rice Research Institute, undated mimeograph, p. 6.

[30] A. N. Duckham and G. B. Masefield, *Farming Systems of the World,* Praeger, 1969, p. 419.

[31] Bradfield, *op cit.*, p. 8.

facilities or create the need for new ones. Some of the early ripening rices, for instance, mature during a wet rather than dry season; this has led to the development and installation of drying facilities. Elsewhere, storage or transportation facilities may be overloaded or inappropriate for new products or patterns. New insect and disease problems may arise. Thus multiple cropping may necessitate new approaches to post-harvest handling.

* * *

Each of the above major ingredients, as well as many others, is needed to provide the biological-physical basis for multiple cropping. Yet each by itself is not sufficient. It must be used in consort with the other factors to provide an appropriate package of inputs. Developing and tying this package together will place a considerable added burden on the research and administrative facilities of most less developed nations. The problem is made no less difficult by the severe time restraints imposed by multiple cropping.

CROPPING SEQUENCES AND YIELDS

A fallow season has traditionally thought been necessary between crops because of the need to accumulate or build up water supplies and for the regeneration of soil fertility and structure.[32] One of the main features of agricultural development, as Boserup has pointed out, is the reduction in this fallow period.[33] Year-round cropping represents, in this sense, the upper limit of development.

Double cropping does not mean that fallow periods are eliminated. Indeed, both crops may be squeezed in one season, leaving a regular fallow period. Alternately, there may still be short fallow periods between the summer and winter crops. Depending on the time of maturation of the individual crop, fallow may not effectively be eliminated until triple or quadruple cropping are attained.

The technical importance of the fallow period varies with the type of culture. Rice paddy land has been intensively farmed in Asia for centuries with little fallowing; this can evidently be done because (1) the flooding process improves the utilization of applied nitrogen and makes phosphorus more readily available, and (2) the rice plant is tolerant of poor soil structure under flooding.[34] Just how long it will be possible to carry out continuous cropping on upland crops without running into serious nutrient or structure problems is

[32] See, for example; Georg Borgstrom, *Too Many: A Study of the Earth's Biological Limitations,* Macmillan, 1969, pp. 40, 41, 193.

[33] Ester Boserup, *The Conditions of Agricultural Growth; The Economics of Agrarian Change Under Population Pressure,* Aldine, 1965, pp. 11-13, 116-121.

[34] W. H. Patrick, Jr. and I. C. Mahapatra, "Transformation and Availability to Rice of Nitrogen and Phosphorus in Waterlogged Soils," *Advances in Agronomy,* 1968 (Vol. 20), Academic Press, pp. 323-359; discussions with Dr. David Bouldin of the Agronomy Department at Cornell University, and Dr. C. Roy Adair of the Agricultural Research Service, USDA.

uncertain.[35] It is a matter which may be of increasing concern to agronomists in the future.

Although the situation varies between paddy and upland soils, the fallow period still does perform several functions. Its reduction lessens these contributions. Thus the shortening of fallow might be assumed to result in a decrease in yields unless the ingredients are provided in some other way. Moreover, the shift from single to double cropping might be expected to accelerate the depletion of these items.

Thus it may be expected—and often happens—that yields of the additional crops are lower. The original crop is presumably grown during the most favorable growing season; additional crops are faced with less favorable periods—possibly a shorter growing period, limited or poorly distributed water supplies, weed, infestations, insect or disease problems, etc. For these reasons, yields of the second crop might be expected to be lower than if the crop were grown during the main season.

This is, however, not always the case. Crops may be grown during one season because under traditional practice one or two limiting factors so dictate (water is a major example), and not because all the major factors favor that period. Otherwise, conditions may favor growing during part or all of the fallow period. Such, in fact appears to be the case in the winter or dry season in parts of Asia. In the Philippines:

> The late dry season, March, April and May, is the best season of the year to the fortunate farmer who has plenty of water to irrigate his farm. Sunlight is abundant, water is under control, mechanical operations can be performed at any time, weed control is easy. Pests are easier to control. Harvesting is less hazardous and can be mechanized. Practically any short season crop will grow well during this season.[36]

Similarly, Wittwer states that in East Pakistan, the best growing season in many respects is from November to April (the boro season); he notes particularly the warm sunny days and cool nights which are favorable for many crops.[37]

For these reasons, the yields of improved varieties of rice in Asia, at various nitrogen levels, are often higher in the dry season (where irrigation is available) than in the wet season. Experimental data verifying this relationship for IR-8 rice in India and the Philippines are presented in Figure 1.[38] During the

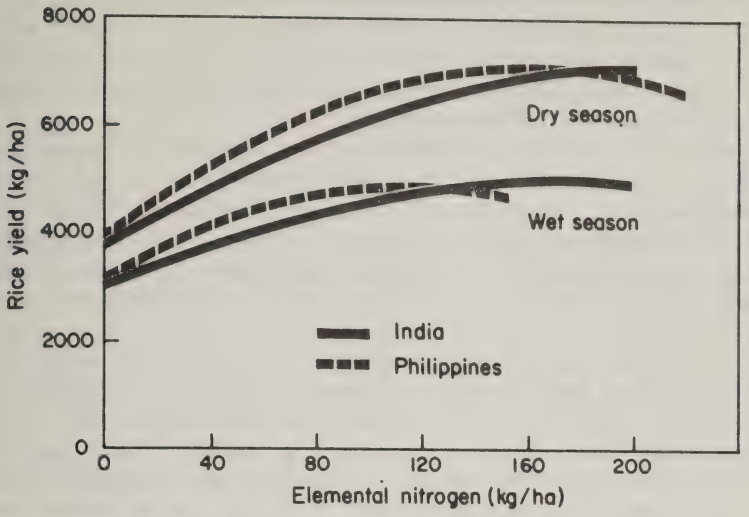
[35] In India, experimental quadruple cropping has been practiced on the same piece of land since 1966-67; through 1969-70 yields had not decreased (Swaminathan and Bains, *op cit.*, pp. 58-59).

[36] Richard Bradfield, "Toward More and Better Food for the Filipino People and More Income for Her Farmers," Agricultural Development Council Paper, New York, December 1966, p. 4.

[37] S. H. Wittwer, Michigan State University, March 1970. Also noted in the report by Carolus and Kazi cited by Margaret Haswell, *Potential for Economic Growth of Resource Development in Asian Agriculture,* SEATO, Bangkok, 1970, p. 38.

[38] Similar data have been reported by: A. A. Johnson of the Ford Foundation in India; Lester R. Brown, *Seeds of Change,* Praeger, 1970, p. 31; and Vernon W. Ruttan," Strategy for Increasing Rice Production in Southeast Asia," in *Economic Development of Tropical Agriculture* (ed. by W. W. McPherson), University of Florida Press, 1968, pp. 177-178.

Figure 1. Yield Response of IR-8 Rice to Nitrogen, Dry and Wet Seasons.



Notes:—India. 1968, 19 locations.
Philippines. 1966-68 average, Maligaya Rice Experiment Station in Central Luzon.
Source:—*1969 Annual Report,* International Rice Research Institute, p. 176.

1968/69 crop year, about 30% of the high-yielding rice in India was planted during the dry (rabi) season.[39]

Where water is in short supply or expensive, it is necessary to give special attention to the water requirements of prospective crops. On this basis rice doesn't rate highly: it needs a great deal of water. Johnson indicates that *three* acres of certain high-yielding grain crops, vegetables, and pulses can be grown with the same amount of water as required for *one* acre of rice.[40] The varying water requirements of various crops in use in multiple cropping in Southern India, for instance, are reported as follows:[41]

Crop and Variety	*Season*	*Water Requirement* (mm.)
Rice (IR-8)	Kharif	1550
Rice (TN-1)	Summer	1250
Cotton	Rabi	564
Ragi (Purna)	Summer	505
Wheat (Mexican)	Rabi	465
Bajra (HB-4)	Summer	447
Jowar (CSH-1)	Kharif	374
Raji (Purna)	Kharif	200
Mung	Rabi	150

[39] Dalrymple, *op cit.* (1971), p. 24.

[40] A. A. Johnson, "The Ford Foundation's Involvement in Intensive Agricultural Development in India—With Emphasis on Multiple Cropping," Ford Foundation, New Delhi, January 1968, p. 9.

[41] H. P. Achar, "Multiple Cropping from Available Irrigation in Southern India," *Indian Farming,* October 1970, p. 32.

(It may be possible to grow paddy rice with less water than is at present utilized, but further study is needed.[42]) Many of these other crops, however, have the disadvantage that they cannot tolerate too much water and they require good aeration. Sorghum is an exception in that it can tolerate both high and low water levels; for this reason it is a promising crop to grow in transition seasons as well as during the dry season.[43]

Considerably more research—both of a cultural and economic nature—is needed to determine the most appropriate dry season crop and the needed cultural practices. In some places (Comilla, East Pakistan for one) the research emphasis has continued to be on rice as a second crop when the benefits of growing alternative crops have been well demonstrated.[44] In some cases, it is difficult to grow upland types of crops on soil which has been previously puddled for paddy rice.

The cultivation of even an appropriate second crop will usually have an effect on the first crop. Some of the possibly unfavorable factors have been noted earlier: depletion of fertilizer and water levels, build-up of insects and diseases, shortening of the season, etc. Yet Barnett reports that in the Philippines in the mid-1960's farmers would raise earlier maturing varieties of rice, even though their yields were lower than longer season varieties, so that they could add a second crop of vegetables.[45] The special practices required for a second crop—such as the installation of an irrigation system, the application of fertilizer, the use of new tillage practices—could well benefit the first crop.[46]

Hence it is difficult to say in advance whether the reduction of fallow involved in multiple cropping will lead to increased or decreased yields of individual crops. But even if individual yields drop, it is likely that total output for a given piece of land per year will increase. And it is total output which is the important factor.

TIMING

As more crops are planted within a given season, and the fallow period between them shortened, it is clear that less time is left between the harvest of

[42] Gale Young, "Dry Lands and Desalted Water," *Science,* January 23, 1970, pp. 340-341. There is, however, a threshold limit below which yields will drop off sharply; see G. Levine, "The Water Environment and Crop Production," in *Some Issues Emerging from Recent Breakthroughs in Food Production* (ed. by K. L. Turk), New York State College of Agriculture at Cornell University, 1971, pp. 380-381.

[43] Bradfield, *op cit.* (1966), p. 5.

[44] Haswell, *op cit.*, pp. 38, 40.

[45] Milton R. Barnett, "Subsistence and Transition in Agricultural Development among the Ibaloi in the Philippines," in *Subsistence Agriculture and Economic Development* (ed. by Clifton R. Wharton Jr.), Aldine, 1969, pp. 287-288.

[46] Should double cropping result in increased yields for both crops as compared to other single cropped areas, this does not establish the inherent superiority of the system; it may well be that the area where the double cropping is carried out is superior and that the single cropping area has some problem ("Multiple Cropping Systems Which Included Corn and Sorghum in Amphoe Phayuha Khiri, Changwat Nakhon Sawan, in 1968 and 1969," Kasetsart University, Department of Agricultural Economics, October 1970, p. 3).

one and the planting of the next. Minimizing the number of days the land is idle, while efficient in terms of land use, provides a special time burden.

A large number of operations need to be carried out in a relatively short period of time. For rice these include: harvesting, threshing, drying, seedbed preparation (plowing, harrowing, puddling), initial irrigation, and planting or transplanting. Not just one farmer is involved; many farmers in a district may be trying to carry out the same operation at the same time.

Similar and simultaneous actions of many farmers can create a real problem in terms of input supplies such as seed, farm chemicals, and irrigation. Multiple cropping not only increases the need for more of these inputs but makes more specific demands on when they are available. In the new Sungei Muda irrigation project in West Malaysia, for example, it was recognized that enormous timing troubles could arise from the servicing of many thousands of farmers simultaneously with inputs and other facilities. So they did, and it was subsequently necessity to rephase the program over longer period of time.[47]

Large influential growers may face less of a problem than small farmers. Consider the situation with respect to canal irrigation as reported by a member of the Indian Planning Commission:

> Irrigation difficulties arise for small and medium farmers who cannot influence the irrigation authority to give water at the proper time to enable them to adopt a multi-cropping pattern of the desired kind.[48]

Tubewells help get around some of these problems because of their greater flexibility in time of operation, but they cannot be used everywhere and the cost of a unit may be too great for small growers.[49]

The importance of a problem like irrigation timing would, of course, vary somewhat with the crop involved. It may well be most difficult in the case of rice double cropping where the paddy fields need to be levelled, flooded, and puddled prior to transplanting. To carry out field preparation operations in Kedah, West Malaysia, using water buffalo, for example, requires 48 to 56 days and can just be fitted into the present single cropping pattern.[50]

Such problems have led to increased interest in mechanization and early maturing varieties of rice. In the Malaysian case, mechanization cuts the field preparation time in half, but "the farmer is still faced with a very tight schedule, allowing little for breakdown in machines or any other emergency."[51] The availability of shorter-season varieties has stimulated consideration of direct seeding instead of transplanting (transplanting was often

[47] Foreign Agricultural Service Reports from Kuala Lumpur: MY0003, February 3, 1970, p. 2; MY0015, September 17, 1970, 2 pp.

[48] Speech of Shri B. Venkatappiah, *Report of the National Seminar on Multiple Cropping*, New Delhi, May 1970, p. 51.

[49] The small farmers may get around this problem in part by some sort of group venture or, as suggested earlier, by buying water from larger growers.

[50] "Muda River Project," *World Crops*, March/April 1969, pp. 14, 16.

[51] *Ibid.*, p. 16. Mechanization is further discussed in Chapter IV.

necessary in order to fit two crops into the available growing season);[52] research work on a paddy seeder is underway at the International Rice Research Institute.

The length of growing season obviously has a major impact on the timing problem. Rice has a longer growing period than other grains or vegetables. Bradfield indicates that in the Philippines the better-yielding varieties now available require about 110 days to mature as compared to 75 to 90 days for crops like corn, soybeans, mungo beans and sweet potatoes, and 60 to 65 days for bush sitao and sweet corn.[53] According to data provided by Lee for Taiwan, the growing period for three of four rice crops is 125 days each (the fourth, the first crop of native rice, requires only 100 days). Requirements for other crops ranged as follows: wheat 120, potato (winter) 110, tobacco 110, rapeseed 105, mustard 103, cabbage 98, Chinese cabbage 95, muskmelon 45.[54] The exact growing period might well vary somewhat with the season involved.[55] Thus the rotations can be arranged, within climatic restraints, to include crops which provide some flexibility on timing.

A number of other ways of reducing the timing problem have been used or are under investigation. Bradfield lists some of these:[56]

> Bed the soil to accelerate the drying of the top layer where crops are to be planted and cultivated;
>
> Keep the volume of soil tilled and the number of tillage operations to a minimum;
>
> Grow ratoon crops where feasible. This eliminates one or two planting operations;

[52] The relative merits of transplanting and direct seeding have been a matter of study for some time in Asia. Investigations were carried out in the Philippines and in China in the mid-30's (as cited in R. B. Bersamin and B. B. Mabbayad, "Yield Response and Agronomic Characters of Lowland Rice Varieties Under Different Methods of Direct Seeding," *The Philippine Agriculturist,* February 1967, pp. 832, 841, 842). Essentially all of the rice grown in the developed nations is broadcast or drilled. Recently the matter has been studied at the Chainat Rice Experiment Station in Thailand and by Bradfield at IRRI.

[53] Bradfield, *op cit.* (1966), p. 5.

[54] T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 10.

[55] In the United States, the variation in heat units associated with different seasons has led to the development of a system for measuring "growing degree days." This method was first commercially used to schedule vegetable planting and harvesting for processing in 1936; it is now widely adopted. For further information, see: H. L. Seaton, "Scheduling Plantings and Predicting Harvesting Maturities for Processing Vegetables," *Food Technology,* April 1955 (Vol. IX, No. 4), pp. 202-209; B. E. Dethier and M. T. Vittum, *Growing Degree Days in New York State,* Cornell University, Agricultural Experiment Station, Bulletin 1017, November 1967, 39 pp. An alternate system involving a "growth unit" measurement was developed at Seabrook Farms but evidently never widely adopted (it is described by C. W. Thornwaite in "Operations Research in Agriculture," *Journal of the Operations Research Society of America,* February 1953, pp. 33-38).

[56] Richard Bradfield, "Increasing Food Production in the Tropics by Multiple Cropping," in *Research for the World Food Crisis* (ed. by Daniel G. Aldrich, Jr.), American Association for the Advancement of Science, Publication No. 92, 1970, p. 236.

Start slow growing vegetables in compact propagation beds and transplant to the field when they reach the period of more rapid growth;[57]

Grow some crops each season which can be harvested and utilized in an immature stage (e.g., sweet corn, edible soys);

Intercrop wherever possible.

Relay interplanting is another practice which is used in several countries in Asia. In Taiwan the practice involves planting a crop such as tobacco, jute, sweet potatoes, or sugar cane on small ridges formed by hand between the rows of paddy rice 10 to 20 days before the harvest. Another variation is the planting of sweet potatoes, peanuts, soybeans, or rapeseed with sugar cane.[58] A similar technique is followed in Madhya Pradesh State in India where linseed or pulse seed may be broadcast among standing rice plants about a month before the rice is harvested in November; the shade provided by the rice plants protects the seedlings from the hot October sun.[59] A different system is followed in East Pakistan: two rices with different growing seasons are sown at the same time; the short season Aus varieties mature in 3 to 4 months, while Aman varieties continue to grow for 7-8 months.[60] Other variants of these systems are undoubtedly practiced.

Even the best of systems, however, are subject to short-term vagaries of the weather. There is little margin in some rotations for delays caused by the weather. In the case of certain kharif crops in India, a delay of one week in sowing reportedly results in delaying maturity by two weeks or more.[61] If a fixed harvest date is followed, a delay in maturity may lessen yield or create problems in harvesting or planting the following crop. Mechanization (to be discussed in Chapter IV), can help get around some of these difficulties.

Timing will, however, long be a problem in multiple cropping.

* * *

[57] It may seem inconsistent to suggest this for vegetables and the opposite for rice. The reason is that transplanting rice is involves an intricate seedbed preparation process which is not necessary for vegetables.

[58] Bradfield, *op cit.* (1966), p. 6; Ho, *op cit.* (1966), p. 99; Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, Taipei, April 1970, p. 8.

[59] "Madhya Pradesh," *Farmers of India,* Indian Council of Agricultural Research, New Delhi, Vol. IV, 1968, p. 48. This is known as the utera crop and is also discussed by Thomas F. Weaver in "The Farmers of Raipur," in *Developing Rural India: Plan and Practice* (by J. W. Mellor et al.), Cornell University Press, 1968, pp. 181-182.

[60] A. Alim (ed.), *Rice Cultivation in East Pakistan,* Government of East Pakistan, Food and Agricultural Council, February 1956, p. 34.

[61] A. S. Kahlon, "Farm Technology—Its Implications in Agricultural Economics," Presidential Address, Indian Society of Agricultural Economics," October 23, 1970, p. 7. During the winter, however, a difference of up to a month in sowing may cause a delay of just one week in crop maturity.

Clearly, the biological-physical aspects of multiple cropping are complicated. They involve a complex interaction of climate, appropriate varieties, water control, fertilization, pest control, cropping sequences, and timing. The relationships, moreover, are further complicated by the fact that they may vary from one region to another and over time. And ecological problems (to be discussed later) can add yet further difficulties.

IV. SOCIAL AND ECONOMIC ASPECTS

Multiple cropping is strongly influenced by a number of social and economic factors. Unfortunately even less work has been done in this sphere than on biological-physical aspects. Still, it is possible to outline some of the major questions which need to be asked and to review such information as seems to exist.

We start by examining a key social area—the relationship of multiple cropping to population and employment. This sets the stage for a review of some of the key economic issues. Finally, social and economic factors retarding adoption are noted.

RELATION OF MULTIPLE CROPPING TO POPULATION AND EMPLOYMENT

In the past, there appears to have been a noticeable correlation between the expansion of multiple cropping and the growth of population. This is not entirely surprising for multiple cropping requires a relatively dense population—both to provide the large amount of labor required in production and to create the demand for increased output.

Multiple Cropping and Population

What is the evidence for thinking that there is a correlation? And given a correlation, what is the nature of the interrelationship? The data which exist on these matters are limited but do provide the basis for initiating discussion.

Examples of Correlation: Examples of a relationship between multiple cropping and population can be found successively at the international, national, and regional levels.

For international comparisons, it may be appropriate to think of population density in terms of the amount of agricultural land per capita. Such data for the major regions are summarized in Table 7. The highest population densities are found in East and South Asia; multiple cropping is most prevalent in these regions. The lowest densities are found in Africa, Latin America and the Near East; with the exception of Egypt, multiple cropping is considerably less common in these areas.

The relationship becomes even more evident when viewed on an individual country basis. Twenty of the most densely populated Asian nations are listed in Table 8.[1] Multiple cropping is found in all, though sometimes on a limited

[1] Japan is included for comparative purposes even though it is clearly not a less developed nation. It is a major food importer.

Table 7.—Estimated Agricultural Land Per Capita
Major Less Developed Regions, Late 1960's
(Excluding Communist Nations)

Region	Acres per Capita
East Asia[1]	0.6
South Asia[2]	0.8
Near East[3]	3.6
Latin America[4]	5.4
Africa[5]	7.1
Total Less Developed Nations	2.7
(Total Developed Nations)	(4.7)

[1] Excludes Japan; when Japan is included the figure is lowered to 0.5.

[2] Afghanistan, Ceylon, India, Nepal, Pakistan.

[3] Includes Egypt and large quantities of rough grazing land in Saudi Arabia.

[4] 19 republics.

[5] Excludes Egypt (included in Near East) and Republic of South Africa.

Source:—*Selected Economic Data for the Less Developed Countries*, Agency for International Development, Office of Statistics and Reports, May 1970, 8 pp.

scale. Those LDC'S with the greatest population density (except for Lebanon) are apt to have a high cropping index; Egypt recently had an index of 166, South Korea 152, Taiwan 184, North Vietnam 147, Mainland China 140-147, Indonesia 126, East Pakistan 139, West Pakistan 110, India 114, and Burma 111. Comprehensive indexes are not available for other nations, but we do have figures for paddy land in some: Ceylon 143, West Malaysia 238, Philippines 115, South Vietnam 113. No data are available for Thailand and Cambodia, but evidently multiple cropping is still limited. Only small areas are multiple cropped in Lebanon and Jordan. (We shall examine the country cropping data in greater detail in the following chapter.)

The correlation between multiple cropping and population may also be evident within the regions of a nation. Based on some data recently reported for East Pakistan for the early 1960's by Revelle and Thomas,[2] a simple correlation was run between population density (in terms of persons per acre on total land area) and cropping intensity for 15 provinces. The simple coefficient of determination (r^2) was .61, which suggests more than a casual degree of

[2] Roger Revelle and Harold A. Thomas, Jr., "Population and Food in East Pakistan," Harvard Center for Population Studies (1969 or 1970), Tables 1 and 2, pp. 29-30.

Table 8.—Estimated Agricultural Land Per Capita, Most Densely Populated Asian and Near East Nations, Late 1960's

Country	Acres per Capita
Egypt	0.2
Japan	0.2
Korea (South)	0.2
Taiwan	0.2
Vietnam (North)	0.3[1]
China (Mainland)	0.3[1]
Lebanon	0.3
Ceylon	0.4
Indonesia	0.4
Pakistan	0.6[2]
Malaysia (West)	0.7
India	0.8
Philippines	0.8
Thailand	0.8
Vietnam (South)	0.8
Nepal	1.0
Cambodia	1.3
Laos	1.4
Burma	1.5
Jordan	1.5

[1] Cultivated land per capita.

[2] The area per capita is much less in East Pakistan than in West Pakistan.

Sources:—*Selected Economic Data for the Less Developed Countries,* Agency for International Development, Office of Statistics and Reports, May 1970, 8 pp. North Vietnam and Mainland China estimates provided by Marion Larsen, Economic Research Service, USDA. Estimates for China in 1952 and 1957 are summarized in Pi-Chao Chen, "The Political Economics of Population Growth: The Case of China," *World Politics,* January 1971, p. 255.

association. Such a relationship might be more evident in East Pakistan than elsewhere because the geographic and climatic variations are probably less than in most nations.[3]

Certain regions in larger nations, however, are also relatively uniform in geographical terms. Ganguli examined the relationships within the Gangetic Valley of India in the 1930's. This was done by comparing data for a large number of governmental units in the valley. He concluded that there was "a statistical correspondence between the high density of population and the *extent* of the double cropped area in the region." Ganguli went a significant

[3] Also, two provinces were left out of the analysis: one was the Chittagong Hill Tracts which are geographically quite unlike the rest of the country, and the other was the capital province of Dacca which is also the site of the largest urban area.

step further in his analysis and considered the *value* of the second crop. When this was done he found "interesting regional contrasts which explain the variations in the distribution of rural density."[4] Value would certainly merit attention as a measure of intensity and might well be tried in other studies.

While the data reported here are far from conclusive or exhaustive, they at least support the suggestion of a hypothesis of correlation between growth in population density and multiple cropping.

Nature of Interrelationship: Simple association or correlation in statistical terms is just that; it does not indicate direction of influence. Is it population density that stimulates multiple cropping, or vice versa? Could multiple cropping stimulate population growth? Or do both factors act on each other with the end result that both increase?

The main theme of a stimulating book by Boserup is that "population increase leads to the adoption of more intensive systems of agriculture."[5] There is some precedent for her observation. David Ricardo in 1821 noted the effect of population growth on land use in these terms:

> . . . every step in the progress of population . . . shall oblige a country to have recourse to land of a worse quality, to enable it to raise its supply of food . . . It often, and, indeed, commonly happens, that before . . . the inferior lands are cultivated, capital can be employed more productively on those lands which are already in production.[6]

The choice in such cases, therefore, is toward a more intensive agriculture.

Where the increase in population is even more rapid than in the England of Ricardo's day, and land even more scarce, the choice is clearer. Ganguli wrote as follows of the Ganges Valley in India in the 1930's:

> When the population multiplies at an alarming rate and there is extreme scarcity of good arable land which can be brought under the plough, one of the alternatives before the farmer is to supplement his income by more extensive double cropping. Thus extensive double-cropping in the densely populated regions surveyed in this work signifies the widespread tendency to resort to more intensive subsistence farming which has been forced upon the cultivators by the growth of population.[7]

[4] Birendranath Ganguli, *Trends in Agriculture and Population in the Ganges Valley*, Methuen & Co., London, 1938, p. xiii (also see p. 57).

[5] Ester Boserup, *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*, Aldine, Chicago, 1965, 124 pp. (quote from p. 118). Also see Boserup, "Present and Potential Food Production in Developing Countries," in *Geography and a Crowding World* (ed. by Wilbur Zelinsky et al.), Oxford University Press, 1970, pp. 100-113. A similar point is made for Western Africa by M. B. Gleave and H. P. White, "Population Density and Agricultural Systems in West Africa," in *Environment and Land Use in Africa* (ed. by M. F. Thomas and G. W. Whittington), Methuen & Co., London, 1969, pp. 273-300.

[6] *Principles of Political Economy and Taxation*, George Bell & Sons, London, 1891, Chap. II, No. 24, p. 47.

[7] Ganguli, *op cit.*, p. xiii (also see p. 57).

Similarly, an evaluation of the evolution of double cropping in Mainland China over the past six centuries led to the observation that ". . . the key to increased grain output from this source was population growth and the increasing density of people in any given area."[8]

Others have noted that while double cropping with rice is only practiced to a limited extent in most countries, ". . . in some areas, especially where the population is dense, it has been customary for centuries."[9] A Dutch agronomist, for example, reports that on densely populated Java, rice production could not keep step with the increase in population after 1900, necessitating increased multiple cropping.[10]

The emergence of multiple cropping in response to these population pressures in turn means that more people can be fed. This is, in fact, often the main goal, but it also means that these additional people will survive to produce yet more children. A more abundant food supply, due in large part to multiple cropping, reportedly enabled China's population to begin to increase relatively rapidly at the beginning of the eleventh century.[11]

Thus there is reason for thinking that population growth and multiple cropping intertwine in an ever-increasing spiral.

Multiple Cropping and Employment

There are essentially three basic labor problems which involve the rural areas: (a) the need for additional total annual employment for landless laborers, (b) the need to reduce seasonal unemployment for those involved in agriculture, and (c) the need for additional labor at key peak periods (such as planting and harvesting) in some regions. In solving (a) and (b), the purpose, of course, would be to increase labor income. The three problems are not entirely mutually compatible in terms of solutions, but multiple cropping can, under certain conditions, make contributions to each.

While there is good reason for thinking that total labor use is increased with multiple cropping, only limited empirical evidence is available. In Taiwan, the increase in labor input per hectare during this century has shown an amazingly close relationship with the increase in multiple cropping. This is illustrated by the following indexes of change:

[8] Dwight H. Perkins, *Agricultural Development in China, 1368-1968*, Aldine, 1969, p. 187.

[9] C. C. Webster and P. N. Wilson, *Agriculture in the Tropics*, Longmans, Green & Co., London, 1966, pp. 206, 207.

[10] As cited in Clifford Geertz, *Agricultural Involution: The Process of Ecological Change in Indonesia*, University of California Press, 1963, p. 96.

[11] Ping-ti Ho, "Early Ripening Rice in Chinese History," *The Economic History Review*, December 1956, p. 200.

Period	Index of Multiple Cropping*	Index of Labor Input**
1911-1915	100	100
1931-1935	113	114
1956-1960	156	155

*Derived from the indexes in Table 5 (p. 19) which were recalculated on a 1911-15 base.

**Derived from data presented by Lee (fn. 56, p. 19), p. 11.

Data of a much more limited nature, representing a sample of progressive farmers in the Punjab during the late 1960's, showed an even sharper increase in labor requirements with an increase in the intensity of cropping.[12] Similarly, a study in the Bicol region of the Philippines in 1968-69 revealed that "in general, the labor input increases as the multiple cropping index increases on both lowland and upland palay (rice)—diversified farms."[13]

Further documentation on this matter would be desirable, but the task will not be easy because of the wide variations in labor needs and the sources of labor.

Varying Labor Needs: The impact of multiple cropping on employment will fluctuate with the intensity of cropping. Intensity of cropping, in turn, is related to the type of water supply, crops, varieties, and cropping frequencies. We do not have sufficient information on these matters, but perhaps the following references will be illustrative:

– Water Supply. The type of water supply can directly affect labor needs and indirectly influence them through the intensity of cropping. The irrigation process itself requires labor; some systems such as those involving wells and tanks (ponds) may require more labor than those involving tubewells or canals.[14] Data from the Philippines suggest that rice farms with high quality irrigation systems utilized considerably more man days per unit of land than did farms with low quality systems (Table 9).

– Type of Crops. Labor requirements for individual crops vary over a wide range, as is illustrated by the statistics for Taiwan in Table 10. Similar data for 11 crops in Central Luzon in the Philippines show a range in requirements from 28 days per hectare for corn to 417 days for onions.[15]

[12] S. S. Johl, "Mechanization, Labor-Use, and Productivity in Indian Agriculture," Ohio State University, Department of Agricultural Economics and Rural Sociology, Occasional Paper No. 23 (1970 or 1971), p. 8.

[13] Cristina Crisostomo, et al., "The New Rice Technology and Labor Absorption in Philippine Agriculture," in *Rice Policy Conference: Current Papers from the Department of Agricultural Economics*, International Rice Research Institute, May 9-14, 1971, p. 17.

[14] Boserup, *op. cit.*, pp. 39-40; Karl A. Wittfogel, "The Hydraulic Civilizations," in *Man's Role in Changing the Face of the Earth* (W. I. Thomas, ed.), University of Chicago Press, 1956, pp. 157-158.

[15] E. A. Bernal, et al., "Unit Requirements, Costs and Returns for Producing Palay and Secondary Crops in Central Luzon, 1962-1963," *The Philippine Agriculturist*, September-October 1964, p. 220.

Table 9.—Labor Input on 118 Farms in Central Luzon and Laguna, 1968 Wet Season

Water Supply	Man Days Per Hectare	
	Local Varieties	HYV
Rainfed	52	51
Irrigation		
Low Quality	60	59
High Quality	66	79
All farms	57	64

Source:—Randolph Barker and Mahar Mangahas, "The Impact of New Technology on Labor Use in Rice Production," International Rice Research Institute, 1971, Table 2.

Table 10.—Labor Requirements for Individual Crops, Taiwan

Crop	Number of Man Days
Potato (fall)	78
Rapeseed	80
Wheat	97
Rice[1]	98-103
Potato (winter)	106
Peanut	107
Sugarcane (fall)	145
Muskmelon	172
Mustard	207
Cabbage	256
Cabbage, Chinese	354
Tobacco	800

[1] Native 2nd crop 98; native 1st crop 99; ponlai 2nd crop 100; ponlai 1st crop 103.

Source:—T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 10.

— Crop Varieties. Improved varieties of grain, especially rice, may require more labor per unit of area, though not per unit of output, than traditional varieties. In one study in the Philippines (Table 9), the labor requirements were about 20% higher for high-yielding rice varieties where high quality irrigation was available (they were little different under rainfed or low quality irrigation conditions); the difference was due to the greater weeding and harvesting and threshing requirements. In another study on 42 rice farms in Laguna, the requirements were about 8% higher, principally due to harvesting and threshing labor needs.[16]

[16] Randolph Barker and Violeta Cordova, "The Impact of New Technology on Rice Production—A Study of Change in Three Philippine Municipalities from 1966 to 1969," International Rice Research Institute, December 1970, Table 11.

– Type of Improved Varieties. Improved varieties may also differ among themselves in their labor requirements. While one survey in the Philippines revealed that IR-8 rice required only slightly more labor per hectare than BPI-76,[17] another survey in the Thanjavur area of India indicated that an acre of IR-8 required approximately 40% more labor than an acre of ADT-27.[18] If yields are taken into consideration, the differences may be less.

– Cropping Frequency. The range in labor requirements is widened as one moves from single to double, from double to triple, and from triple to quadruple cropping. Unfortunately data on actual hours of labor used (as opposed to cost of labor) seem to be very scarce, particularly with respect to the move from single to double cropping. In Chekiang Province in China in the mid-1950's, the change from single to double cropping of rice increased the demand for labor by 80%.[19] The labor requirements for triple cropping were up to two to three times greater than for double cropping in Taiwan, depending on which of several types of rotations are involved.[20] Quadruple cropping is likely to raise the lower end of this range, but is doubtful that the upper limit is raised much except in cases of very intensive vegetable culture.

Labor Sources and Shortfalls: It is not certain just how much of the increased labor required by multiple cropping would be allocated between (1) a net expansion in jobs, and/or (2) a reduction in unemployment of existing farm labor. Experience in West Pakistan and Taiwan indicates that an increase in multiple cropping has led to a less than comparable increase in the farm labor force, suggesting a substantial degree of previous underemployment.[21] The situation may vary with type of operator: further production may be unattractive to large operators who hire laborers, but may still be considered desirable to small farmers who do all their own labor.[22] Lee has indicated that the small-scale farmers on Taiwan "have adopted labor-intensive cropping in order to absorb more family labor."[23]

Severe underemployment may indeed exist on family farms much of the year. Farm management studies in India have shown that nearly ¼ of the family labor engaged in traditional farming is not gainfully employed because

[17] Randolph Barker and E. U. Quintana, "Farm Management Studies of Costs and Returns in Rice Production," International Rice Research Institute, 1968, p. 34. Based on survey data gathered in 1965/66 and 1966/67.

[18] C. Muthiah, "The Agricultural Labor Problem in Thanjavur and the New Agricultural Strategy," *Indian Journal of Agricultural Economics,* July-September 1970, p. 20.

[19] Kenneth R. Walker, *Planning in Chinese Agriculture,* Aldine, 1965, p. 64.

[20] Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, Taipei, April 1970, p. 10.

[21] John Cownie, B. F. Johnston, and Bart Duff, "The Quantitative Impact of the Seed-Fertilizer Revolution in West Pakistan: An Exploratory Study," *Food Research Institute Studies,* 1970 (No. 1), pp. 64, 72.

[22] Folke Dovring, "Unemployment in Traditional Agriculture," *Economic Development and Cultural Change,* January 1967, p. 169.

[23] T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 13.

farm operations are not spread over the year (similarly, bullocks are not used for any operations over half of the time).[24] Increased multiple cropping can clearly contribute to shortening slack periods during the year (in turn leading to increased farm income).

At the same time, however, multiple cropping is bound to exacerbate seasonal labor shortages at planting or harvesting time. Multiple cropping in the Thanjavur area of India has led to a 60% increase in labor demands over a short period. Labor costs at such periods, especially in fertile areas such as the Punjab, are already commonly much higher than during other portions of the year. Moreover, there can be an actual shortage; Perkins reports that for several provinces in China, ". . . the available labor supply is on the average less than half that necessary for ideal double cropping conditions."[25] As we will see in Chapter V, labor shortages, in part due to industrial development, have contributed to a drop-off in multiple cropping in Japan and Taiwan.

The problem of season peaks in labor demand could be alleviated by steps which would (a) lengthen the amount of time available during the planting or harvesting period, or (b) speed up these processes. Some of these techniques have already been discussed. To accelerate operations, mechanization has often been used or suggested. As Heady and Agrawal put it, by speeding critical operations such as land preparation, harvesting, or threshing, mechanization can allow addition of a crop which lessens the underemployment of labor in other seasons and provides a more stable employment over the year.[26] A recent analysis in the Punjab area in India suggests that "tractors do influence the intensity of cropping and thereby increase the requirements of labor."[27] Other data also suggest an increase in tractor use with increased multiple cropping.[28] Some economists feel that mechanization may only be justified in a social sense in terms of the impetus it may give to multiple cropping. Still, this relationship may not hold in every area. Moreover, it will be difficult to limit the use of machinery on other labor-intensive operations at other times of the year.

* * *

In total, it appears that multiple cropping can make significant—if not yet fully quantified—contributions to increasing farm employment. Indeed, Heady and Agrawal have suggested that for the next two decades perhaps, "multiple cropping promises to be a more effective means of creating employment for

[24] "Pilot Project for Multiple Cropping," *Report of the National Seminar on Multiple Cropping,* New Delhi, May 1970, p. 16. Severe underemployment is also reflected in P. C. Goswami and C. K. Bora, "Demand for Labor in Rural Areas of Assam: A Case Study in Nowgong District," *Indian Journal of Agricultural Economics,* July-September 1970, pp. 46-52.

[25] Perkins, *op. cit.,* p. 45.

[26] Earl O. Heady and R. C. Agrawal, "Prospects and Problems in Multiple Cropping," *Report of the National Seminar on Multiple Cropping,* New Delhi, May 1970, p. 83.

[27] Martin H. Billings and Arjan Singh, "Employment Effects of HYV Wheat and Its Implications for Mechanization," US/AID, New Delhi, 1970, p. 17.

[28] Johl, *op cit.,* p. 8.

the growing and already large population in rural areas than does the prospect of industry."[29] But to make all of this possible, ways may have to be found to help get around problems of seasonal labor shortages without contributing to an eventual weakening of the employment situation the remainder of the year.

BASIC ECONOMIC QUESTIONS IN ASSESSING MULTIPLE CROPPING

Multiple cropping involves a number of thorny economic questions. They arise at the social (public or government) level and at the private (farm) level. In each case, the increased costs of multiple cropping must be evaluated against increased returns. Government planners will be concerned with the question of whether multiple cropping is the best use of scarce resources. Farmers will be concerned with profitability. And both planners and farmers will want to select the most optimal cropping sequences. The limited economic knowledge available about multiple cropping does not provide quick or easy answers. The best we can do at this point is outline some of the major issues involved.

Is Multiple Cropping the Best Social Use of Resources?

If single cropping is the prevailing system, the initial question is whether it is desirable or worthwhile to try to produce additional crops. Would it be better for the government to devote scarce public resources exclusively to expanding production under the present system or to devote part of them to encouraging the culture of a second or third crop? While we will pose the question in terms of economics, it must be recognized that actual government policy may be influenced by a number of other factors.

Main Considerations: Among the basic social factors in assessing the desirability of multiple cropping, aside from its effect on employment (discussed in the previous section) might be its potential effects on: (1) quantity, quality and price of food to the consumer, (2) income distribution between small and large farms, (3) foreign exchange costs, and (4) utilization of human resources.

It is a goal of nearly every government to make more and nutritionally better foods available to consumers at a lower price. Multiple cropping holds definite promise of expanding total agricultural output and of making it possible to grow a wider variety of crops. Expanded output can help meet caloric needs. The potentially increased variety could include crops which provide a better nutritional balance. In each case, the expanded output should lead to lower consumer prices. The critical factor in all of this, however, is whether sufficient effective consumer demand is present to keep farm prices at a level which will stimulate production. If not, the government may have to—as it usually does—step in with some sort of purchase and welfare program. The presence of a new second or third crop, therefore, can distrub existing price support and purchase programs. Consequently, the evolvement of a whole new series of competitive and complementary relationships means, as Gotsch

[29] Heady and Agrawal, *op. cit.*, p. 83.

and Falcon note, that price policy must be considered in a multicrop, general equilibrium setting.[30]

The small farmer is often bypassed in the course of technological progress, further widening existing economic gaps. Multiple cropping, in contrast, has evidently been as readily adopted on small as large farms. Massive surveys in Mainland China in the 1920's and 1930's revealed no significant relation between farm size and degree of multiple cropping.[31] If there is a relation, it may be that smaller farmers have a higher cropping index. This, in fact, has recently been indicated in studies in India,[32] East and West Pakistan,[33] Korea,[34] and the Philippines.[35]

The foreign exchange costs of multiple cropping as compared to alternative agricultural programs are unclear at this point. Nearly all production programs require increased inputs of farm chemicals and improved water control.[36] If these inputs must be imported, then most any program will involve a foreign exchange cost. Multiple cropping might, however, have particularly great requirements for fertilizer and irrigation (and hence irrigation equipment). The matter bears further investigation.

Multiple cropping, as was suggested in the previous chapter, also requires a great deal of scientific, technological and administrative know-how. These are among the scarcest of items in less developed nations. Moreover they can be costly. Will their investment in multiple cropping pay higher dividends than elsewhere? One might like to think so, but it would be difficult to be certain.

Where do we come out? Multiple cropping, from a social point of view, appears to hold promise of: improving employment, reducing rural income disparities, and expanding the quantity and quality of output. On the other hand, multiple cropping may increase foreign exchange cost for certain inputs, and increase the demands on scarce human administrative and scientific skills. Still, on balance, multiple cropping appears to be a most promising use of resources.

[30] Carl H. Gotsch and Walter P. Falcon, *Agriculture Price Policy and the Development of West Pakistan,* Organization for Social and Technical Innovation, Cambridge, Vol. 1, February 1970, pp. 2, 11.

[31] John Losing Buck: *Chinese Farm Economy,* University of Chicago Press, 1930, pp. 190, 196; *Land Utilization in China,* University of Nanking, 1937, p. 216.

[32] Umanada Phukan, *A Study on Double Cropping in Sibsagar District, Assam (1968-69),* Assam Agricultural University, Agro-Economic Research Centre for North East India, p. 56; S. L. Shah and L. R. Singh, "The Impact of New Agricultural Technology on Rural Employment in North-West U. P.," *Indian Journal of Agricultural Economics,* July-September 1970, pp. 30-31.

[33] *Farm Management Research in Pakistan* (Ministry of Agriculture and Works, Planning Unit): August 1968, "Farm Management Report on Muzafargarh Project," p. 34; January 1969, "Report on Hazara Project," p. 14; May 1969, "Report on Comilla Project," p. 15; October 1969, "Survey Report on Hydrabad Project," p. 21; December 1969, "Farm Management Survey on Rajshahi Project," p. 10.

[34] Young Kun Shim, *Economic Analysis of Double Cropping in Paddy Fields,* Seoul National University, College of Agriculture, Code No. 66-26, 1967 (distributed in 1969), p. 29.

[35] Chrisostomo, et al., *op. cit.,* p. 17.

[36] In addition, the use of these inputs may lead to ecological problems, a matter which will be discussed in the last chapter of this report.

Current Issues: The question of whether multiple cropping is the best use of resources in agriculture is of more than theoretical concern in some nations.

In West Pakistan, the World Bank has studied the question of whether to use limited water resources to extend the total irrigated area or to make more intensive use of existing irrigated lands through multiple cropping. According to a recent report, the Bank's recommendation was to ". . . intensify cropping on a 30 million acre land base over the Perspective Plan period (1965-85) rather than to expand total irrigated area."[37]

In Thailand, there has been a recent debate over whether it would be better to use limited resources on expanding the output of the main rice crop or to use part of them to produce a second crop. With the completion of the Phumiphon Dam, some sections of the Thai Government, the Ministry of Interior in particular, were anxious to promote as much double cropping of rice as possible. The Department of Rice, on the other hand, was reported believing that the same resources could produce more rice if they were concentrated on one main crop.[38]

In East Pakistan, the water supply situation is somewhat different from Thailand. Much of the land is flooded annually and adequate residual moisture is left for a winter (rabi) crop. Yet there is not enough moisture for the traditional crop of East Pakistan, rice. Thus despite a favorable climatic situation and an extremely heavy population, much of the potentially arable land is let go fallow. One potentially strong prospect is expanded potato production. The key problems seemed to be lack of technical know-how, inappropriate seed stock, and lack of seed storage facilities. All could be solved, but they would require both scarce technological and capital resources.[39]

The economics of government investment in multiple cropping vis-a-vis other alternative programs in agriculture, therefore, are a real question and will undoubtedly be of increasing concern in the future.

What are the Costs and Returns at the Farm Level?

From what has been said so far, it would be expected that costs per unit of land per year are higher for multiple cropping than for single cropping, but that gross returns are even higher, so that net returns are increased. The net returns for individual crops involved in multiple cropping rotations, however, may each be less than if they were grown under single cropping; the critical point is that in aggregate for the year they exceed those for single cropping. Just how much higher they need to be to tempt the farmer to adopt them would probably vary considerably according to the farmer's financial position, his motivation, and local customs and habits.

[37] Cownie, et al., *op. cit.*, p. 67 (fn. 9).

[38] T. H. Silcock, *The Economic Development of Thai Agriculture*, Cornell University Press, 1970, p. 64. (Similar remarks are provided by Silcock in his chapter on "Thailand" in *Agricultural Development in Asia* [ed. by T. T. Shand], University of California Press, 1969, pp. 134-135.) Neither group seems to have given much attention to the farmers' attitudes.

[39] Dana G. Dalrymple and Robert F. Akeley, *The Potato Industry in East Pakistan: Improving Seed Multiplication and Storage*, U.S. Department of Agriculture, International Agricultural Development Service, May 1968, 99 pp.

Unfortunately, financial data on the costs and returns to multiple cropping appear to be very limited. Thus the few studies reported in the following paragraphs are only illustrative; I have no idea if they are widely representative. This is yet another area where much more study is needed.

Costs: The extent to which costs of raising a second crop will raise total costs will depend in part on the degree to which underutilized resources are present. If sufficiently well-watered land is available, there is an adequate growing season, and draught animals and labor are unemployed or underemployed, costs will be lower than they otherwise might be. But if, for instance, planting and harvesting dates overlap, and harvest labor is already short, labor costs could be extremely high and would lead to the need for mechanization; mechanization in turn might lower the per unit cost but could require extensive capitalization which would be out of the reach of many farmers. Water supply could be a particular problem; reliance on artificial supplies of any kind—but particularly pumps—is bound to be more expensive than rainfall.

Labor Costs: We have noted the increase in labor normally required as a shift is made from single to double cropping, and from double cropping to higher multiples. We have also noted that labor requirements vary according to the types of crops included in the rotations.

Naturally these factors will be reflected in labor costs. The increases in labor costs involved in moving from single to double cropping, and from double cropping to higher frequencies, are indicated in data from the Philippines (Table 11)[40] and Taiwan (Table 12). Similarly, other studies have shown the wide variations in labor costs among different cropping frequencies (Table 13).

It is not certain, however, whether the labor costs increase directly with labor requirements. The answer depends on the degree to which hired or family labor is utilized. This in turn depends in part on the degree of underemployment of family labor and on the amount and timing of labor needs by individual crop rotations. For example, of the total amount of labor required for 12 different double cropping rotations in Central Luzon, the proportion of hired labor utilized varied from 52.5 to 32.3%. Hired labor requirements were particularly high for rotations involving two crops of rice; this was because the pulling of seedlings and the transplanting were done on a contract basis.[41] Hence labor costs cannot be imputed directly from labor requirements.

It is not clear from these studies what kind of price was attributed to family labor. It would be desirable to know this in order to determine the returns to capital and management.

Capital Costs: Capital costs also vary widely. In a recent Philippine study, rice double cropping involved less capital than diversified single cropping while double cropping involving a second crop other than rice required 45% more capital (Table 11). The Taiwan study revealed a sharp jump in capital costs in

[40] In the case cited, however, the added labor was considerably higher when the second crop was something other than rice (e.g. vegetables).

[41] Bernal, *op. cit.*, pp. 207, 221.

Table 11.—Costs and Returns Under Three Cropping Systems, Bicol, Philippines, 1968-1969

Cropping Index	Cropping System	Number of Farms	Labor (mandays)	Operating Capital (P)[1]	Net Return (P)[2]
			—per hectare—		
100	Lowland rice diversified	24	185	93	698
200	Lowland rice - lowland rice	46	200	73	662
200	Lowland rice - other crops[3]	32	263	135	1060

[1] In Philippine dollars. Includes all variable costs except wages for hired labor and value of shares for harvesting and threshing services.

[2] In Philippine dollars. Return above variable costs (which include expenses for fertilizers, insecticides, wages of hired labor and value of shares for harvesting and threshing).

[3] Include vegetables such as cabbage and tomatoes.

Source:—"Annual Research Review: Agricultural Economics," International Rice Research Institute, February 9, 1971, p. 2, table 17.

Table 12.—Indexes of Costs and Returns Under Three Intensities of Multiple Cropping, Taiwan, 1965

Cropping Index	Rotation	Index of Cost			Index of Returns	
		Labor	Capital[1]	Total	Gross	Net
200	rice—rice	100	100	100	100	100
300	rice—rice vegetable	163	158	160	158	156
400	rice—vegetable —rice—vegetable	184	158	170	185	206

[1] Seed, fertilizer, animal or machinery, pesticide, and other.

Source:—Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, April 8, 1970, p. 10 (Based on "Report on Economic Survey of Land Utilization and Crops Production in Taiwan," JCRR Special Report No. 42, 1965).

moving from double to triple cropping, but no further change involved in moving from triple to quadruple cropping (Table 12).

As before, the range is wide within the triple cropping category. For the six rotations in Taiwan, the range was from an index of 100 to a high of 284. For the ten triple cropping rotations in India, the range was from an index of 100 to 196.

Capital costs are perhaps a matter of greater concern to smaller than larger growers. Capital is typically not readily available to the smaller growers. This could well prove to be a handicap in the adoption of multiple cropping or of some rotations.

* * *

Table 13.—Variability of Labor Costs Under Various Multiple Cropping Rotations

Country and Region	Cropping System	No. of Rotations	Range of Labor Costs (index)
India/Uttar Pradesh*	Double	10	100-233
Philippines/Central Luzon**	Double	11	100-235
Taiwan***	Triple	6	100-300

Sources:—

*_New Intensive-Cropping Rotations in Tari,_ U. P. Agricultural University, Experiment Station, January 1968, pp. 17, 44-47.

**E. R. Bernal, "Unit Requirements, Costs and Returns for Producing Palay and Secondary Crops in Central Luzon, 1962-1963," _The Philippine Agriculturist,_ September-October 1964, p. 221.

***Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, Taipei, April 1970, p. 10.

While the data are not entirely clear, it seems clear that multiple cropping, especially of the more intensive forms, brings about an increase in both labor and capital costs. Labor costs are perhaps of primary concern to larger growers, while capital costs may be a greater problem to small growers.

Net Returns: Returns from multiple cropping, as might be expected, are highly variable. Two of the more prominent factors may be (1) frequency of cropping, and (2) type of crops included in a given frequency.

While some increase in net returns might be expected in moving from single to double cropping, the progression is not always an even one. For instance in the Philippine study noted previously (Table 11), the returns from double cropping were higher than for single cropping only when the second crop was other than rice (in which case they were 52% higher). In another Philippine study the average returns moved as follows on a small number of farms growing rice and other crops:[42]

Type of Rice	*Average Cropping Index*	*Index of Returns Above Variable Costs per Hectare*
Lowland	103	100
(27 farms)	147	432
	182	243
	205	584
Upland	100	100
(23 farms)	125	128
	155	52
	200	180

Returns initially increased, and then dropped off before climbing again.

[42] Moises L. Sardido, "Income Distribution Patterns of Rice Farms in Bicol," _Seminar on Economics of Rice Production in the Philippines_ (December 1969), Departments of Agricultural Economics, University of the Philippines and the International Rice Research Institute, p. 4-27.

Still, these and some other studies reveal a certain tendency for returns to increase with cropping frequency. In Taiwan, when the returns for double cropping were set at 100, the index of net returns for the triple cropping was 156, while the index for quadruple cropping was 206 (Table 12). Similarly in another study in India (again compared to an index of 100 for double cropping), triple cropping produced an index of 149, while quadruple cropping had an index of 191. Compared to single cropping of rice, the Indian data showed the following progression:[43]

Cropping Index	*Rotation*	*Net Returns* (index)
100	rice–fallow	100
200	rice–wheat	200
300	rice–wheat–moong	297
400	maize–potato–wheat–moong	382

Just how representative these statistics are is not certain.

Within the various cropping intensities, different rotations provided quite different net returns. Among six triple cropping rotations in the Taiwan case noted above, the index of returns varied from 100 to 158. In the case of ten triple rotations in India, the index ranged from 100 to 188. And in the Philippines it varied from 100 to 343.

Beyond variability, there are several other problems in interpreting net return calculations. First, only the better farmers may attempt the more complicated cropping practices, so that the increased return is in part a function of management skill. Secondly, the studies may include a current price. The effect of an increase in production (through the adoption of a new cropping system) on price is usually not determined. This is an important constraint because the total market for some products is not large and expanded production may bring about sharp price drops. Thirdly, net returns may not be defined the same way in every study. And with the great variability in tenure arrangements, it may be difficult to settle on a common meaning. For these reasons, returns data may often be suspect.

Another basic point is that even with more intensive rotations, overall returns to farmers may still be low compared to the rest of society. And in some cases where average farm size holding is very small, it may be necessary for the operators to move to the higher rotations just to maintain a minimal income. For these individuals, multiple cropping is a last chance, not a step into affluence.

How Can Cropping Interrelationships be Analyzed in Economic Terms?

The basic element of multiple cropping is an ordered sequence of crops. Individual crops in a sequence, as suggested in the previous chapter, may have a number of possible cultural interrelationships. These both influence and complicate the final selection of sequences. Some interrelationships, however, can be expressed in economic terms and analyzed. They run the gamut from

[43] Prem Singh and S. D. Choubey, "For Jabalpur an Intensive Cropping Schedule," *Indian Farming*, November 1969, p. 23.

the elementary to the very sophisticated. Both extremes will be briefly noted here.

Generalized Output Interrelationships: Alternative crops strive, as Alfred Marshall once put it, against each other for possession of the land.[44] The nature of this competition, however, is modified by the way the various crops in a rotation relate to each other. In terms familiar to the economist, they may be competitive, complementary, or supplementary (independent). In each case, the classical assumption is that the total amount of inputs remains constant. This assumption, as we have inferred earlier, may not always be correct for multiple cropping if underutilized resources are available. Still the general relationships will exist, if in modified form. We shall review them in terms of double cropping.[45]

Pure Forms: The two crops involved in double cropping can relate to each other in three basic ways. The pure forms may be described as follows:

- *Competitive.* In this relationship, the output of one crop can be increased only through a drop in production of the other. Given limited physical (fertility, water) and human resources (labor, management), as well as time restraints, this might be expected to be a common relationship. That is, if a farmer decides to concentrate his resources on one crop, he will have less to apply on the other.
- *Complementary.* In this case, an increase in output of one crop helps bring about an increase in the output of the other. This relationship is undoubtedly considerably less common. A traditional example is the effect of a legume crop on subsequent crops. But a complementary relationship could also occur when, for instance, the application of water or fertilizer to one crop leaves a reserve which may be utilized by the following crop. Or to carry this a step further, the provision of irrigation for one crop may also mean that it is available for other crops in a rotation.
- *Supplementary* (or Independent). In this situation, the output of one crop can be increased without having any influence on the output of the other. Heady notes that these situation arise when (a) "enterprises can be produced during a distinct and limited period of the year," and (b) "the resources employed give off a flow of services over all time periods."[46] Clearly this would apply to double cropping where there are two well separated seasons, where adequate fertility and moisture are available for both crops, and where there is underemployed labor the year around.

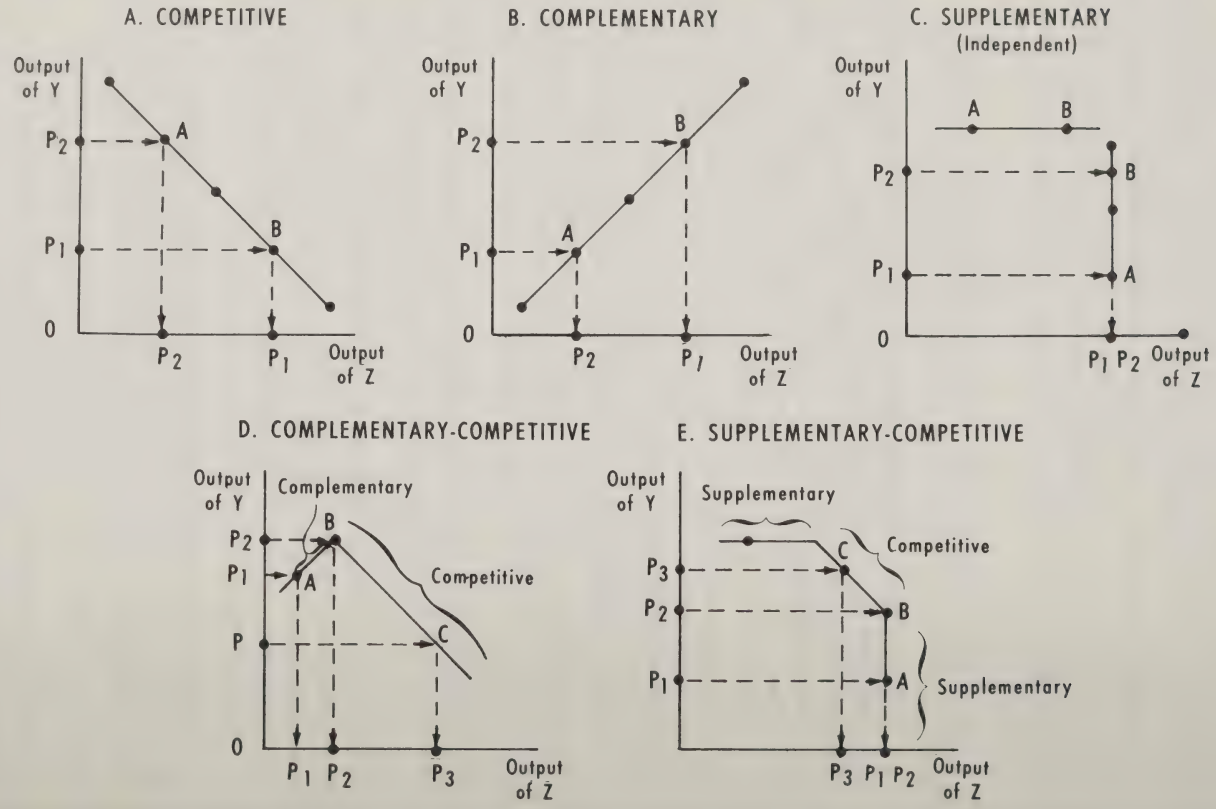
The pure forms of these relationships are presented geometrically in Figure 2, A-C. The solid lines represent the production possibilities line. The dotted lines indicate the varying amounts of Z which would be produced as output of

[44] Alfred Marshall, *Principles of Economics,* Macmillan, London, 1920 (8th edition; first published in 1890), p. 361.

[45] This discussion has in part been developed from material presented by Earl O. Heady in *Economics of Agricultural Production and Resource Use,* Prentice Hall, 1952, pp. 201-234.

[46] *Ibid.,* p. 231.

FIG. 2.--PRODUCT–PRODUCT PRODUCTION POSSIBILITY LINES



Y is expanded from P1 to P2, or a movement from A to B along the product possibility line.[47] While the production possibilities have been presented in linear form, in reality the relationships are likely to be curvilinear.[48]

Mixed Forms: But if one is to talk of reality, it must be admitted that pure forms of the complementary and supplementary relationships are unlikely to be found. Combinations of each involving a competitive relationship are more apt to be the case.

- *Complementary-Competitive.* In this case, increased output of one might initially bring about some increase in output of the other. But beyond a certain point they would lapse into a competitive relationship. This is noted geometrically in Figure 2D (as above, the lines might be curvilinear rather than linear). This example could occur when, to borrow from the earlier example, the residual moisture or fertility from the first crop was not adequate to support more than modest increases in output of the second crop.
- *Supplementary-Competitive.* In this case, the output of each crop could initially expand independently of the other, but beyond a certain point they too would lapse into a competitive relationship. This is depicted in Figure 2E (the competitive relationship, again, could be curvilinear rather than linear). This relationship could occur fairly often, because some resources may become limiting only beyond a certain point. That is, production of each crop which initially expanded independently of the other, might soon begin to compete for resources.

We shall encounter further examples and variations of all these relationships in the country summaries which follow.

Development of Optimum Sequences: It is often a complex matter to select from alternative crops in a single cropping system. Indeed the matter has been of interest to economists dating back to the 1800's. The process was subsequently complicated by the introduction of year-to-year rotations. Alfred Marshall stated, with great prescience, that:

> The whole problem might be expressed in simple mathematical phrases. But they would be tedious, and perhaps unfruitful. They would therefore not be serviceable, so long as they remained abstract; though they belong to a class which may ultimately be of good use in the higher science of agriculture, when that has advanced far enough to fill in realistic details.[49]

[47] The relationships could be reciprocal (using the existing dotted lines except in the case of C where vertical lines would have to be entered).

[48] In the case of competitive crops, for example, the straight line relationship represents a constant rate of substitution between the two products. If the rate is not constant, the relationships will be curvilinear. If there is an increasing rate of substitution (successive increases in output of one product entailing increasing sacrifices in the other product), the relationship will be convex from the origin or will bulge out. If there is a diminishing rate of substitution (successive increases in output of one product entail decreasing sacrifices in the other product), the relationship will be concave to the origin.

[49] Marshall, *op. cit.*, p. 361 (fn. 1).

Agricultural science has advanced to this point in developed nations and a great deal of work has been done in working out optimum year-to-year rotations. Except for cover crops, however, few if any of these rotations involve multiple cropping.

The process of determining optimum multiple cropping rotations is, in fact, still in its infancy in most regions in the less developed world. The basic patterns have long been set in some areas, and often involve monoculture, usually of rice. New technological developments have broadened the range of possible crops. At the same time the increased alternatives make the choice more difficult; they are simply beyond what one farmer is able to test. Some nations such as India have a large number of sequences under study (we shall review some of these later in this report) but most are just getting work underway.

The problem of selection was recently well illustrated in Thailand. With the completion of the Greater Chao Phya Delta Project, multiple cropping became possible. The question was what to grow as the second crop. One group advocated the double cropping of rice over as wide an area as possible. Another group suggested the introduction of dry upland crops, stating that water conditions were still not good enough for double crop rice. The peasants were reported ". . . not yet in a position where they can determine which cropping pattern is best suited to the new water conditions."[50]

Linear programming, now a standard management tool in the United States, could be of considerable assistance in working out optimum multiple cropping systems. Lee, for instance, has recently used linear programming to develop separate rotations for paddy and upland rice in Taiwan.[51] The job, however, is not an easy one, particularly if more than two crops and seasons are involved. Heady and Agrawal have done preliminary conceptual work on some of the more complex multiple cropping combinations possible in India.[52]

Though the task is difficult enough purely in terms of production economics, yet other variables should probably be taken into consideration. These are social in nature, and include employment, nutrition, and consumer price. The object of multiple cropping should be not only to increase incomes to producers, but also to lower price and improve nutrition of consumers. One recent linear programming study for a district in Madhya Pradesh in India, for instance, suggests specialization in cereal production.[53] Pulse and vegetable production was held to a minimum. This may make economic sense to the producer, but it doesn't do much for the quality of nutrition. It should be possible to program in such constraints.

FACTORS RETARDING OR INFLUENCING ADOPTION

The most obvious deterrent to adoption of multiple cropping—lack of sufficient increased return to the producer—has been alluded to. What other economic and social factors may be important?

[50] Shigeru Ishikawa, *Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand*, Asian Development Bank, Manila, 1970, p. 84.

[51] Lee, *op. cit.*, pp. 13-21.

[52] Heady and Agrawal, *op cit.*, pp. 87-95.

[53] Vishnoo P. Shukla, *An Economic Analysis of Farm Resource Use, Jabalpur District, Madhya Pradesh, India, 1967-68*, Cornell University, Department of Agricultural Economics, Occasional Paper No. 26, January 1970, p. 60.

Alfred Marshall once stated that the switch to more remunerative crops might be "retarded by habit, or diffidence, or obstinancy, or limitations of the cultivator's knowledge; or by the terms of his lease"[54] This list is remarkably appropriate for multiple cropping.

Perhaps the factor most readily understood is that multiple cropping, despite its promise of higher returns, means more work on the part of the farm operator. Some individuals may not feel the added returns are worth it.

The attitude of at least some Asian farmers, for instance, reflects a more relaxed outlook towards material things than is found in the West. Bloodworth describes the attitude of one portion of the population in these terms:

> Buddhism has taught the Lao that he must cast off ambition, that nothing fails like success, and this suits him down to the ground. When provided by solicitous Americans with new strains of seeds that would double his rice crop, he remarks with pleasure that now he need sow only half his usual acreage.
>
> "What would I do if I worked harder and earned more money?" said a Cambodian farmer ". . . I don't know. I already have a bicycle and a radio. Get another wife perhaps?"
>
> It is not surprising if many Laos look askance at modernization and miracle rice, for instinct tells them correctly what will next come to pass: . . . more human involvement. Man should not meddle.[55]

Not everyone will agree with these comments. Economists will point out that many, if not most, Asian farmers have tangible wants and are willing to work to fulfill them, conditions permitting. Still, at least some farmers may fit Bloodworth's descriptions.

Similarly in Africa, in the Lower Casamance of Senegal, it is reported that a shift to multiple cropping of rice "would eliminate the few months of summer leisure that the Diola now enjoy." Probably the only incentive to give this up, according to de Sapir, would come from a surging demand for cash.[56]

The interest in leisure may stem from other than personal inclination; it may be due in part to a debilitating climate, health problems such as parasites which sap energy, and inadequate diets.[57]

Multiple cropping not only may cause a significant change in the accustomed rhythm of life, as Myrdal puts it,[58] but the change in cropping patterns may run afoul of some unexpected customs. Johnson, for instance, reports that rice is the prestige crop in much of India, both for production and

[54] Marshall, *op. cit.*, p. 361.

[55] Dennis Bloodworth, "The East Thinks West is Filthy," *Washington Post*, September 30, 1970 ("Outlook"). A similar reference is found in his book *An Eye for the Dragon; Southeast Asia Observed: 1954-1970*, Farrar, Straus & Giroux, 1970, pp. 301-302.

[56] Olga Linares de Sapir, "Agriculture and Diola Society," in *African Food Production Systems: Cases and Theory* (ed. by P. F. M. McLoughlin), The Johns Hopkins University Press, 1970, p. 226.

[57] The potential influence of human parasites is discussed by Leland D. Lambert in "The Role of Climate in the Economic Development of Nations," *Land Economics*, forthcoming.

[58] Gunnar Myrdal, *Asian Drama*, Pantheon, 1968, Vol. II, p. 1285.

consumption, and that a change to coarser grains may be resisted.[59] Also in India, it has been the practice in many villages to let cattle range over land fallowed in the off-season. If crops are to be grown on part of this former grazing area, cattle will have to be excluded. This leads to two difficulties: (1) the cost of fencing or the need to tether cattle, and (2) the loss of grazing rights. The former problem has been noted in a study in India.[60] Clark thinks that the latter could be serious:

> These grazing rights . . . are among the most valuable possessions of the poorest families, who will defend them to the last. The situation bears an unhappy resemblance to the English enclosures of the 16th to 18th centuries, which were necessary for the improvement of agricultural efficiency, though carried out with grave social injustice.[61]

Just how widespread the question is, as Clark has presented it, is uncertain.

Another problem may be presented by water and rent charges. In one area in India, it was found that multiple cropping was more apt to be practiced where the rent was fixed for a piece of land for the year (presumably on the basis of a single crop) than where it represented a share of the output.[62] Alternately, some landlords will charge the same rent for land which is used for a second crop even though the yields may be lower.[63] Much the same is true of irrigation charges. In the Comilla area of East Pakistan, Haswell reports that the system of imposing water charges in no way reflects the economic cost of producing various crops under irrigation in the dry (rabi) season.[64]

Other reasons for not taking up multiple cropping are varied. Some which were noted in India were: bird problems (it was necessary to man a watch for the crop from daybreak to sunset for at least a month); lack of time on the part of small farmers with other jobs; shortage of labor on larger farms; shortage of bullocks on smaller farms; less acceptability and lower prices for the second crop; and reduction of first crop when double cropping was practiced.[65] Rats have been a negative factor in the Philippines: in three rice regions during the 1967-68 season, the area planted to a second crop on farms with a rat problem was half that on farms with no rat problem.[66]

[59] A. A. Johnson, "The Ford Foundation's Involvement in Intensive Agricultural Development in India, with Emphasis on Multiple Cropping," New Delhi, 1968, p. 9.

[60] Phukan, *op. cit.*, pp. 48-49.

[61] Colin Clark, *Starvation or Plenty?* Taplinger Publishing Co., 1970, p. 51.

[62] Speech of Shri B. Venkatappiah, *Report of the National Seminar on Multiple Cropping*, New Delhi, May 1970, p. 50.

[63] Myrdal, *op. cit.*, Vol. II, pp. 1285-1286.

[64] Margaret R. Haswell, *Potential for Economic Growth of Resource Development in Asian Agriculture*, SEATO, Bangkok, 1970, p. 39.

[65] Phukan, *op cit.*, pp. 48-49. Also see Brook Greene, *Rate of Adoption of New Farm Practices in the Central Plains, Thailand*, Cornell University, Department of Agricultural Economics, Occasional Paper No. 41, July 1971, Chp. 7.

[66] Zenaida F. Toquero, "Pump Irrigation in Laguna, Batangas and Quezon, 1967-1968," *Seminar on Economics of Rice Production in the Philippines* (December 1969), Departments of Agricultural Economics, University of the Philippines and International Rice Research Institute, pp. 6-21, 6-25.

Additional factors may limit the types of crops grown under multiple cropping systems. The previous Indian study noted that those farmers considering double cropping thought almost entirely in terms of adding a second crop of rice.[67] Similarly, in the Philippines there are rice farmers who are neither willing nor able to produce second crops other than rice. Some of the reasons for this, as noted by Barker, are the facts that: many irrigation systems have poor water control and are suited only for rice production; traditional production programs have emphasized rice production; and existing marketing channels are oriented to rice. In view of these problems, it is often easier to continue producing rice than to diversify into other crops.[68]

* * *

Clearly the social and economic aspects of multiple cropping are no less complicated than the biological and physical aspects. Three major points have been outlined in this chapter: the relation of multiple cropping to population and employment, basic economic questions, and factors influencing or retarding adoption. Each is complicated enough by itself. But in reality each intertwines with the other, making analysis that much more difficult. And other issues and factors could undoubtedly be added. The economic and social aspects of multiple cropping provide no shortage of challenges for further study.

[67] Phukan, *op. cit.*, pp. 48-49.

[68] Randolph Barker, "The Status of Agricultural Development in South and Southeast Asia as a Result of the New Food Grain Technology," International Rice Research Institute, June 1971, p. 2.

V. REVIEW OF RECENT COUNTRY DATA

The basic general features of multiple cropping have been outlined in the previous chapters. Since the exact nature of multiple cropping varies considerably, we now turn to brief reviews of the situation in 25 less developed nations and Japan.[1] Emphasis is placed on recent data on the extent of multiple cropping and the types of cropping systems.

The extent of coverage from country to country, it will quickly become evident, varies considerably. For some of the 25 nations very little information was found and only a paragraph or so is presented. For others, such as India, considerably more data is reported. Fortunately, the amount of information available seems to be roughly related to the importance—in total area or index—of multiple cropping in the nation.

Nearly all of the countries reported are in Asia: only Egypt, Nigeria, and Rhodesia are included from Africa; and Brazil, Guatemala, and Mexico from Latin America. Much of what some might call multiple cropping in these continents is excluded because it is part of shifting agriculture.[2] Moreover, these regions have less irrigated land and are less densely populated than Asia. Still, more multiple cropping may exist in Africa and Latin American than is suggested here.

Hopefully this information will help fill out the more general points discussed in earlier chapters and further suggest areas of possible future research or study.

BRAZIL

Multiple cropping in Brazil centers around double crops of (a) wheat and soybeans, (b) dry and wet season peanuts, and (c) dry and wet season beans. Most of this cropping is found in the southern part of the country. In addition, potatoes are double cropped in some regions.

The wheat-soybean rotation is a good example of complementarity. In Rio Grande do Sul area, the wheat crop is harvested in December and the land then

[1] Japan is included because its multiple cropping pattern is built around rice, the basic crop in many rotations in other nations in Asia. Limited data for the United States are presented in Appendix A.

[2] Shifting agriculture was discussed in Chapter I. Other variants include semipermanent cultivation involving five to ten years of continuous cropping followed by a fallow period of approximately equal length; such practices may be found on alluvial or flood plains such as along the Zambezi River or in the Kilombero Valley in Africa (Thayer Scudder, "Kariba Dam: The Ecological Hazards of Making a Lake," *Natural History*, February 1969, p. 70; R. Jatzold and E. Baum, *The Kilombero Valley*, Wellforum Verlag, Munich, Afrika Studien 28, 1968, pp. 33-95). Some permanent multiple cropping may exist in such areas.

plowed and planted to soybeans. The same tractors and combines used for wheat are also employed for soybeans. Often farmers do not add additional fertilizer for soybeans, relying instead on the residual effects of wheat fertilization. It has been estimated that every commercial wheat farmer (every farmer cultivating at least 250 acres) in Rio Grande do Sul utilizes a wheat-soybean rotation. Most observers feel, it is reported, that mechanized soybean production is of marginal profitability unless wheat is also produced on the same land; possibly 20% of the soybeans are raised in this way.[3]

Peanut double cropping is practiced in Sao Paulo and Parana. The dry crop is usually planted on land previously occupied by a wet crop; the process reportedly enables farmers to economize in land preparation operations. The wet crop is harvested during December–February and the dry crop from April to June.[4]

BURMA

Although Burma has a long history of irrigation,[5] little is known about multiple cropping. In recent years, several million acres have been multiple cropped (Table 14). The expansion of double cropping has borne a close relation to the expansion of irrigation. Future growth is reported to be dependent on the extension of tractor plowing; the work is stated to be beyond the capacity of bullocks.[6] Rice forms the basis for the rotation, but it is not clear what is planted as the second crop.

A study of a village of 113 farmers in lower Burma in 1959-1960 indicated that 300 acres out of 1700 were double cropped, for an index of 117.6. Groundnuts (peanuts) were planted as the second crop by 94% of the farmers. This practice originated in the village in 1956. It has reportedly proved quite successful, due primarily to three factors: (1) there is an assured market and adequate transport facilities; (2) little capital outlay is needed because of the availability of land, labor, and a simple technology; and (3) the crop makes an important and inexpensive contribution to the diet and is a significant source of cash income.[7]

CAMBODIA

Multiple cropping has been practiced for centuries in Cambodia. Under the Khmer emperors a complex system of hydraulic works were built in the

[3] Peter T. Knight, "Agricultural Modernization in Rio Grande do Sul," US/AID/Brazil, May 1969 as cited in Foreign Agricultural Service Report BZ-9078 from Rio de Janeiro, November 6, 1969, p. 11 and in letter from Shackford Pitcher, Acting Agricultural Attache, American Embassy, Rio de Janeiro, August 17, 1970. Further details on the economic aspects of these operations may be found in J. J. de C. Engler and I. J. Singh, "Production Response to Technological and Price Changes: A Study of Wheat and Cattle Farming in Southern Brazil," Ohio State University, Department of Agricultural Economics and Rural Sociology, Occasional Paper No. 33, 1971, 25 pp.

[4] "Producao e Comericalizacao de Amendoim no Estado de Sao Paulo," *Agricultura em Sao Paulo,* January/February 1967 (cited by Pitcher, *op. cit.,* August 17, 1970).

[5] N. D. Gulhati, *Irrigation in the World: A Global Review,* International Commission on Irrigation and Drainage, New Delhi, 1955, pp. 12-15.

[6] H. P. Richter, "The Union of Burma," in *Agricultural Development in Asia* (ed. by R. T. Shand), University of California Press, 1969, pp. 156, 178.

[7] David E. Pfanner, "A Semisubsistence Economy in Lower Burma," in *Subsistence Agriculture and Economic Development* (ed. by C. R. Wharton, Jr.), Aldine, 1969, p. 51.

Table 14.—Multiple Cropped Area and Indexes, Burma

Period	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1936/37 to 1940/41 avg.	1,218	107.0
1961/62	1,315	107.4
1962/63	1,658	108.7
1963/64	1,895	109.6
1964/65	2,036	110.4
1965/66	2,162	111.1

Source:—H. P. Richter, "The Union of Burma", in *Agricultural Development in Asia* (ed. by R. T. Shand), University of California Press, 1969, pp. 154, 156.

Mekong River basin nearly 1000 years ago which made triple and quadruple cropping possible.[8]

Yet today Cambodia is not known to practice multiple cropping to any great extent. As elsewhere, some vegetables may be grown on paddy fields after harvest for family use. And multiple cropping of vegetables is found along some river banks.[9] No quantitative data, however, are available on the extent of such practices

Recently the Israelis have been assisting a test farm in Prey Phdau, in one of the poorest farming areas of the country, in anticipation of completion of the nation's first reclamation project. This area had meager rice crops in the wet season and was not able to grow anything in the dry season. With irrigation it is possible to get two rice crops a year, and experiments have shown that with maximum irrigation three crops a year can be grown. The Israelis have also shown the Cambodians how to grow other crops to permit diversification.[10]

CEYLON

Double cropping in Ceylon is largely tied to rice. It is estimated that 563,400 acres of rice, 43% of the total rice area, was double cropped in 1966.[11] The proportion was higher in the wet zone, which has two monsoons;

[8] Malcolm MacDonald, *Angkor*, Jonathan Cape, London, 1958, p. 67; Maslyn Williams, *The Land in Between: The Cambodian Dilemma*, William Morrow, 1970, p. 37; Claire Sterling, "Mekong Project Points Up Superior Wisdom of Ancients," *Washington Post*, May 11, 1971, p. A18.

[9] Jean Delvert, "The Cambodian Peasant," Joint Publications Research Service (JPRS:14,709), August 1962, pp. 446-468, 473-488. (Translation of *Le Paysan Cambodien*, Paris, 1961.)

[10] "Israelis Help Test Farm in Cambodia," *Washington Post*, July 1, 1970, p. F1.

[11] Noboru Yamada and Bhakdi Lusanandana, "Rice Production in the ADB Region," in *Asian Agricultural Survey*, Asian Development Bank, Manila, Vol. II, March 1968, p. 26.

it was lower (35%) in the dry zone, which generally needs irrigation water in both seasons.[12]

Several irrigation projects in the dry zone are expected to being about an increase in the double cropped area. The Mahaweli Ganga project will make possible a second crop on 300,000 acres already in rice production, and it will reclaim 600,000 acres of new land on which double cropping will be possible. The Walawe project in southern Ceylon will bring 65,000 acres of new land into production which will be able to produce at least two crops a year.[13]

Just how much of the second crop area is planted to crops other than rice is uncertain.[14] In the hill country around Rahangala, however, thousands of acres are now sown to potatoes after rice. The fact that the paddy land is flooded reportedly reduces the incidence of bacterial wilt on potatoes.[15]

CHINA (Mainland)

More land is probably multiple cropped in Mainland China than in the rest of the less developed world combined. In view of the long history of multiple cropping in China, and the immense size and population of the country, extensive multiple cropping is to be expected.

Estimated Area and Indexes

The estimated area involved and cropping indexes for the 1952-1959, and 1968 period are presented in Table 15.[16] The data for the 1950's seem to be fairly well established and accepted. More recent national statistics have not been released and it was only possible to piece together a 1968 estimate; as footnote 2 to Table 15 indicates, there is a difference of opinion on what the figure should be.

The index, in any case, is considerably higher in southern China than in northern China. Yueh, who compiled the national index of 147.4 for 1968 reported in Table 15, indicated that the index in the south was 189.3, while it averaged only 119.0 in the north. One researcher who placed the national figure at 145.9, calculated an index of 187.0 in the south and 118.5 in the north.

The cropping index is highest in the provinces of Chekiang, Kwangtung, and Kiangsi. Provincial estimates vary more widely than the regional figures, but it appears that each was over 200 in the 1968 season and may have ranged from 235 to 237. According to one source, Hunan (also in the south) may also have been over 200, although another places it at less. Other provinces with indexes

[12] *Ibid.*; D. H. Grist, *Rice,* Longmans, London, 1959 (3rd edition), p. 136. In the dry zones, irrigation is needed as a supplement during the Maha season and is virtually the complete source of water during the Yala season (P. Richards and E. Stoutjesdijk, *Agriculture in Ceylon Until 1975,* OECD, Development Center, Paris, 1970, p. 47).

[13] S. H. Wittwer, "Maximizing Agricultural Production," Michigan Agricultural Experiment Station, Journal Article 4885, October 1969, p. 10 (based on a trip to Ceylon, August 1969).

[14] In much of the dry area, there is a tradition of using irrigation water only on rice (Richards and Stoutjesdijk, *op. cit.).*

[15] Wittwer, *op. cit.*

[16] Green manure crops (principally vetches grown in the Yangtze Valley) are included.

Table 15.—Multiple Cropped Area and Indexes, Mainland China

Year	Multiple Cropped	
	Area[1]	Index
	(1,000 acres)	
1952	82,359	130.9
1953	87,719	132.7
1954	95,289	135.3
1955	101,104	137.2
1956	116,973	142.3
1957	112,195	140.6
1958	119,773	145.0
1959	103,117	138.9
1968[2]	127,388	147.4

[1] Converted from mou on the basis of 1 mou = .1647 acres. Includes green manure crops.

[2] Some qualified observers feel that the 1968 figures reported here are too high. One suggests that the actual situation more nearly approached 1957. Another places the index at 145.9.

Sources:—

1952-58. *Ten Great Years*, State Statistical Bureau, Peking, 1960, pp. 128-129. (Summarized in FAS report noted below.)

1959. Official sources.

1968. Derived from data compiled by Tung Yueh and reported in Foreign Agricultural Service Report No. HK0022 from Hong Kong, March 24, 1970, p. 3.

ranging from 160 to 200 include Kwangsi, Szechwan, Kiangsu, Anhwei, Hupei, Fukien, Kweichow, and Honan.

Forms of Multiple Cropping

The main forms of multiple cropping in Mainland China, moving north to south, are: (a) winter wheat followed by coarse grains such as millet or corn; (b) winter wheat followed by industrial crops such as oilseeds, tobacco, or cotton; (c) rice followed by a winter crop of barley, pulses, or rapeseed; and (d) two crops of rice.

Among individual crops, winter wheat is apparently most important in terms of double cropped area occupied. The relative distribution of area was reportedly about as follows in 1957:[17]

Winter wheat	45%
Rice	15
Pulses	15
Barley	7
Rapeseed	5
Other	12

[17] Dwight H. Perkins, *Agricultural Development in China, 1368-1968*, Aldine, 1969, p. 46. On a production basis, rice would of course rate much higher because of its relatively heavy yield.

Compared to similar data reported in Chapter II for 1931-37, the areas planted changed as follows: wheat +12.0%; rice +77.1%; pulses +51.5%; barley -43.3%, and rapeseed -55.7%.

While these crops are the main ones used in double cropping rotations, other crops are involved in a vast array of combinations. Some of the more unusual or interesting sequences include: cotton—cotton (Anhwei Province), cotton—winter wheat (Hupeh), corn—rice (Kwangsi), corn—soybeans (Hunan), corn—corn (Hunan, Kwangsi, Kweichow), rice—tobacco (Kwangsi), and rice—jute (Kwangtung).[18]

Some triple cropping is practiced. In the most southern portions of the country—the Luichow Peninsula and the island of Hainan—attempts have been made to move from double to triple cropping of rice wherever fertilizer and manpower are adequate.[19] It was recently reported that a commune in Tzekam succeeded experimentally in growing three crops of rice in 1969/70 and subsequently introduced triple cropping on more than 2,300 acres.[20] Somewhat to the north—where the frost-free season is still over 300 days—double cropping of rice may be followed by a winter crop of wheat. In the area along the south bank of the Yangtze, triple cropping may involve winter wheat, summer rice, and an autumn coarse grain or potatoes.[21] As with double cropping, many other combinations are utilized in these and other regions. Vegetable crops, as elsewhere, may be planted in more intensive rotations. The total area more than double cropped, however, is likely still very small.

Communist Policy

Multiple cropping has been promoted since the Communist regime came to power in 1949. There are only limited possibilities for land reclamation in the most important agricultural provinces. During the 1950's emphasis was placed on the development of two-crop rice; somewhat less attention was given to expanding rotations involving winter crops such as wheat or barley.[22]

In either case, the programs met with mixed success. The expansion of double cropped rice proved practical in the portions of south and central China with sufficient water supplies; the program was less successful elsewhere, particularly east China, primarily because of the relatively short growing season and shortages of labor at critical times. The expansion of winter crops in north China was limited by the fact that the cultivation of winter crops delayed the sowing of spring grains until summer, which in turn meant that they could not mature before arrival of bad weather. In some areas, therefore, the combined yield from double cropping was less than for single crops.[23]

[18] Based on information provided by Dr. Louis Erisman.

[19] Owen L. Dawson, *Communist China's Agriculture: Its Development and Future Potential*, Praeger, 1970, p. 224.

[20] "Mass Campaign for Agricultural Scientific Experiments in Full Swing in South China," New China News Agency, Kwangchow, October 15, 1969 (reported in "Survey of China Mainland Press," October 23, 1969).

[21] Dawson, *op. cit.*, p. 234.

[22] Perkins, *op cit.*, p. 45; Foreign Agricultural Service Report No. HK0022 from Hong Kong, March 24, 1970, p. 6.

[23] Based on information supplied by Dr. Lewis Erisman. Also see Kang Chao, *Agricultural Production in Communist China, 1949-1965*, University of Wisconsin Press, 1970, pp. 166-167.

Shifts in individual cropping patterns were also involved. Some of the increase in the double rice cropped area represented a shift from intermediate rice. The wheat area actually may be declining in favor of corn, millets and sorghum. Further, emphasis on increasing the area of green manure crops south of the Yangtze may have cut into the winter crop area.[24]

Current emphasis seems to be on further expansion of double cropping of rice. In order to accomplish this, the regime has been expanding irrigation facilities, providing more fertilizer, encouraging interplanting, and pushing the development of early ripening varieties.[25]

EGYPT

As would be expected from its historical development, multiple cropping is extensively practiced in Egypt. Just how much land is involved, and what the cropping index is, are matters of some uncertainty. One set of data are reported in Table 16. Another report indicates that in 1965 the multiple cropped area was 4.2 million acres and the cropping index 166 (though elsewhere in the same report the index is placed at 160).[26] The data seem to suggest a decline in multiple cropping from 1956 to 1965 but we cannot be sure because the data may not be comparable.

In any case, it is expected that the completion of the Aswan High Dam will make it possible to increase the intensity of production on 700,000 acres in Upper Egypt, in part at least, through a shift from annual to perennial irrigation.[27] How much this area will be multiple cropped is presently unclear; one report suggests it might be about 350,000 acres,[28] while another study places the figure at about 200,000 acres.[29] Hopefully more information will become available on this point.

As of 1965, the basic crop rotation extended over four years (it is outlined in Table 17).

GUATEMALA

A limited amount of corn is double cropped in Guatemala. In 1964, about 105,000 acres were planted to a second corn crop. This was nearly 10% of the area planted to the first corn crop. Yields on the second crop were about 73% those of the first; they were relatively highest (85%) on the smallest farms. Some 221,000 acres of corn are also interplanted with other crops.[30]

[24] Based on information provided by Marion Larsen.

[25] Report HK0022, *op. cit.*, p. 6; "Chinese Agricultural Scientists Cultivate and Popularize Good Seeds," New China News Agency, Peking, December 11, 1969 (reported in "Survey of China Mainland Press," No. 4522); Lee Lescaze, "Fat Grain Harvest Rewards Red China's Agricultural Push," *Washington Post*, August 2, 1970, p. A23.

[26] Cline J. Warren, *Agricultural Development and Expansion in the Nile Basin*, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 48, October 1968, pp. 8, 13.

[27] Claire Sterling, "Aswan Dam: Predictions Came True With a Vengeance," *Washington Post*, February 15, 1971, p. A 18. For a detailed analysis as of 1964, see Wyn F. Owen, "Land and Water Use in the Egyptian High Dam Era," *Land Economics*, August 1964, pp. 277-293.

[28] Sterling, *op. cit.*, p. A-18.

[29] Warren, *op. cit.*, p. 12.

[30] L. B. Fletcher, et al., *Guatemala's Economic Development: The Role of Agriculture*, Iowa State University Press, 1970, pp. 78-82.

Table 16.—Multiple Cropped Area and Indexes, Egypt

Season	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1950/51	3,657	165
1952/53	3,726	166
1956/57	4,556	179
1961/62	4,388	173

Source:—Donald C. Mead, *Growth and Structural Change in the Egyptian Economy,* Irwin, 1967, Appendix Table III C-1.

Table 17.—Basic Crop Rotations, Egypt

Year	First Crop	Second Crop
1	Berseem (clover)[1] or fallow	Cotton
2	Wheat, barley vegetables or berseem	Rice or Corn
4	Berseem (clover)[1] or fallow	Cotton

[1] Berseem occupies about 1/3 of the arable land during the winter because of the pressing need for animal feed. Some economists have suggested that it might be more profitable to import feed and raise vegetables for export on this land. (Memo from John B. Parker, Economic Research Service, USDA, May 12, 1971.)

Source:—Cline J. Warren, *Agricultural Development and Expansion in the Nile Basin,* U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 48, October 1968, pp. 8, 13,

INDIA

India has the second largest multiple cropped area in the world, but her multiple cropping index is relatively low considering population density. In recent years the multiple cropped area has averaged about 50 million acres, but the cropping index has only been around 115 (Table 18). The rate of increase in the index from 1949/50 to 1966/67 has been slight; it may actually have decreased during the drought years of the mid 1960's. National data for more recent years, when multiple cropping may have expanded, are not yet available.

Even in some of the northern states where multiple cropping has been practiced since antiquity, the index is not exceptionally high. In 1965/66, the top four states—accounting for 56% of the total multiple cropped area—were: Bihar, 129; Jammu and Kashmir, 127.7 (a sharp increase from 1956/57); Uttar

Table 18.—Multiple Cropped Area and Indexes, India

Season	Multiple Cropped	
	Area[1]	Index
	(1,000 acres)	
1949-50	38,108	112.0
1950-51	32,486	111.1
1951-52	34,181	111.6
1952-53	35,169	111.5
1953-54	38,730	112.4
1954-55	40,119	112.7
1955-56	44,861	114.1
1956-57	45,916	114,2
1957-58	41,340	113.0
1958-59	48,928	115.0
1959-60	49,136	115.0
1960-61	48,330	114.7
1961-62	51,266	115.3
1962-63	50,465	115.0
1963-64 (p)	50,468	115.0
1964-65 (p)	51,931	115.2
1965-66 (p)	47,119	114.0
1966-67 (p)	48,456	114.4

[1] Area cropped more than once.

Sources:—1949-50 to 1965-66. *Statistical Abstract, India, 1968,* Central Statistical Organization, Department of Statistics, New Delhi, 1969, p. 56 (and earlier issues).

1966-67. "Department of Agriculture Pilot Project for Multiple Cropping," in *Report of the National Seminar on Multiple Cropping,* New Delhi, May 1970, p. 14.

Pradesh, 127.3; and Punjab, 126.8. Other leading states were: Orissa, 124.3 (a sharp increase from 1956/57); Kerala, 123.6; Madras, 119.1; Assam, 118.9; and West Bengal, 117.4.[31]

Within Punjab, data from a sample of progressive farms show a rather striking increase in the cropping index in the late 1960's: from a figure of 126.7 in 1966/67 to 144.3 in 1969/70. This region, however, is perhaps the most advanced agriculturally in the nation and has been in the forefront of the Green Revolution.[32]

Influence of Irrigation

Normally one expects the cropping index to be higher in irrigated than in non-irrigated areas. This, however, is not the case in India where the indexes

[31] *Statistical Abstract, India, 1961, 1968,* Central Statistical Organization, Department of Statistics, New Delhi, pp. 30 and 56 respectively.

[32] S. S. Johl, "Mechanization, Labor Use, and Productivity in Indian Agriculture," Ohio State University, Department of Agricultural Economics and Rural Sociology, Occasional Paper No. 23, (1970 or 1971), p. 8.

for both have been about the same at 115.[33] A surprisingly large portion (82%) of the double cropped area is reportedly in rainfed rather than irrigated areas. Clearly, as an Indian report recently stated, "the irrigated potential has not so far contributed significantly to the increase of intensity of cropping."[34]

One of the major reasons irrigation has not played a larger role has already been discussed (Chapter III): the inadequate nature of much of the present irrigation system. In many areas barely enough water is available to supplement natural rainfall during the wet season, let alone provide adequate water for a second season. In the Western portion of the Gangetic Plain, for instance, the kharif rains are highly variable; irrigation water supplies are not similarly flexible except where pumpsets are available.[35] Timing of delivery is also a problem with canal irrigation.

Other reasons for the relatively low incidence of multiple cropping include: (1) the reverse problem of excess water and inadequate drainage in many areas, (2) low soil fertility, and (3) a shortage of labor during the period when harvesting and planting functions overlap. In the eastern half of the Gangetic Plain it has traditionally been difficult to grow a crop of wheat after rice because the rice is harvested so late that the wheat cannot be planted soon enough; hence yield and profitability are depressed.[36]

Improvements in irrigation associated with the recent expansion of tubewells in some areas may well provide a more positive stimulus to multiple cropping.

Expansion of Multiple Cropped Area

India has a well-defined program to expand the multiple cropped area. The Ford Foundation also has a complementary Intensive Agricultural Districts Program.

One of the earliest concentrated efforts to increase multiple cropping was made in Tanjore. There, during the middle 1960's, out of some 1.2 million acres of rice, only 25% or 300,000 acres were double cropped. A project was initiated to convert the single cropped land to double cropping by use of a new early maturing variety (ADT-27); the area so planted increased from 200 acres in 1964 to 200,000 in 1966. As of 1970, perhaps half the area was sown more than once.[37]

A more general multiple cropping effort was undertaken in 1967/68. During 1968/69, some 15 million acres of a number of crops were covered under the

[33] W. E. Hendrix, "India, Slow and Rapid Growth," in *Economic Progress of Agriculture in Developing Nations, 1950-68,* U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 59, May 1970, p. 151.

[34] "Pilot Project for Multiple Cropping," *Report of the National Seminar on Multiple Cropping,* New Delhi, May 1970, p. 15.

[35] John W. Mellor, "The Evaluation of Rural Development Policy," in *Developing Rural India: Plan and Practice* (by Mellor, et al.), Cornell University Press, 1968, pp. 43, 351.

[36] *Ibid.*

[37] "Rice Crop Proves Tanjore Program's Worth," *Foreign Agriculture,* March 4, 1968, p. 7; James E. Wimberly, "Double-Crop Paddy in India; Mechanical Dryers Help Make it Work," *World Farming,* May 1968, p. 20; C. Muthiah, "The Agricultural Labor Problem in Thanjavur and the New Agricultural Strategy," *Indian Journal of Agricultural Economics,* July-September 1970, p. 20.

program. A target of 19.45 million acres was established for 1969/70, or an increase of 4.45 million acres. The aim is to raise two to three crops a year in fully irrigated areas and two crops in partially irrigated mono-cropped areas. The techniques involved, in addition to new varieties, include improved irrigation and management practices. Members of the Ford Foundation in September 1970 indicated that 51 pilot projects in multiple cropping would be launched.[38]

The amount of multiple cropping achievable in the future is uncertain. It will depend, of course, on the possibilities for introducing new crops and for expanding irrigation, fertilizer and other inputs. Well irrigation is expected to be particularly important.[39] Taking current plans into account, the National Council of Applied Economic Research in New Delhi has recently made some projections of multiple cropped area as part of a larger project. The projections are summarized in Table 19. Using 1964/65 as a base, it will be noted that the

Table 19.—Projections of Possible Multiple Cropped Area and Indexes, India[1]

Season	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1964/1965	49,900	115.2
1970/71	61,800	117.7
1975/76	81,500	123.7
1980/81	103,500	129.7
1985/86	111,200	131.0

[1] Projections for 1975-76 and thereafter estimated on basis of "increase in the irrigated land available for cultivation . . . and in the light of the measures to be taken by the Government to introduce short duration varieties of crops."

Source:—Calculated from data in "Demand and Supply Projections of Food Grains for India, 1970-71 to 1985-86," Center for Agricultural and Economic Development, Iowa State University, DSR-3 (preliminary), October 1970. (Based on work by the National Council of Applied Economic Research, New Delhi.)

[38] *Annual Plan, 1969-70,* Government of India, Planning Commission, p. 48; *Report, 1969-70,* Government of India, Department of Agriculture, p. 21; A. A. Johnson and K. E. Eapen, "A Review of India's Package Program," *Foreign Agriculture,* September 21, 1970, p. 11.

[39] John W. Mellor, "Prospects, Problems and Lessons" in *Developing Rural India; Plan and Practice, op. cit.,* p. 351. In a recent study in the Punjab, noted earlier, the cropping index was projected to increase only on land irrigated by wells; the indexes for nonirrigated and canal irrigated lands remained the same (Martin H. Billings and Arjan Singh, "Farm Mechanization and the Green Revolution, 1964-1984, The Punjab Case," US/AID, New Delhi, April 22, 1970, p. 70).

multiple crop area is expected to double by 1980/81 and the cropping index to increase from 115 to 131. An ambitious target.

Types of Sequences

Many multiple cropping sequences are needed in a country as large and varied as India. In normal practice, double cropping may be the maximum possible under natural rainfall conditions. Where irrigation is present, triple cropping may be practiced.

Common double cropping rotations include: hybrid maize–wheat, hybrid jowar–wheat, hybrid bajra–wheat, rice–wheat, and rice–rice. Rice double cropping, as in other nations, is the most demanding with respect to water; the introduction of the early-maturing varieties, however, has facilitated its adoption (as well as, in some regions, the use of a rice–wheat rotation).[40]

Triple cropping rotations have perhaps been the most widely studied. This has in part been accomplished by replacement of the traditional summer green manure crop with a short-duration pulse crop (such as moong),[41] grain (such as cheena)[42], or forage (such as jowar). It was reported that during 1968/69, maximum production from three grain crops was achieved from maize–wheat–cheena and rice–rice–rice rotations.[43] Rice triple cropping, however, is not widely practiced. In North Bihar, a rice–rice–wheat rotation has been tested along with an alternate involving rice–corn–wheat.[44] Reportedly profitable rotations tested elsewhere include: radish–wheat–jowar and potato–wheat–jowar,[45] corn–potato–potato, corn–potato–tobacco, and maize–potato–pumpkin.[46]

A particularly comprehensive and complete economic evaluation of alternative triple cropping rotations was conducted for the Tari region in Uttar Pradesh, an area well supplied with water. The guiding principal in establishing the rotations was the maximization of overall profits per acre per year. Ten "highly profitable" rotations were proposed; they are summarized with relevant economic data in Table 20. The corn–potato–corn rotation appeared to be most profitable. Selection of the most appropriate rotation, however,

[40] R. T. Gandhi, "Impact of High-Yielding Varieties on Cropping Patterns and Irrigation Policies", in *7th NESA Irrigation Practices Seminar*, US/AID, Lahore, 1968, p. 99.

[41] Ibid., pp. 99, 101.

[42] D. M. Maurya, "Cheena–A Ideal Crop Between Rabi and Kharif," *Indian Farming*, March 1970, p. 25.

[43] M. S. Swaminathan, S. S. Bains, et al., "Latest Technology for Multiple Cropping–Principles, Practices and Problems," *Report of the National Seminar on Multiple Cropping*, New Delhi, May 1970, p. 70.

[44] P. N. Narula and D. P. Misra, "A Three-Crop Sequence for North Bihar," *Indian Farming*, August 1969. In the former rotation, TN-1 or Padma was planted for the first crop and IR-8 for the second. Another reference noted that Padma, though inferior to IR-8 in yield, has better grain quality and matures about two weeks earlier (K. S. Dargan, et al., "Performance of Jute and Rice Varieties in Multiple Cropping Programme," *Indian Farming*, March 1970.

[45] P. N. Arora and S. L. Pandey, "Intensive Rotations are Remunerative," *Indian Farming*, July 1969, p. 30.

[46] Vishnu Prasad, "A Profitable Crop Rotation for Farrukhabad," *Indian Farming*, November 1969, p. 28.

Table 20.—Indexes of Labor Requirements and Net Returns Under Various Triple Cropping Systems, Uttar Pradesh, India, 1967

System	Input Requirements				Net Returns[2]	
	Labor[1]		Capital			
	Index	(Rank)	Index	(Rank)	Index	(Rank)
Maize–potato–maize	100	(1)[5]	100	(1)	100	(1)
Soybean–wheat–cheena[3]	43	(9)	52	(6)	86	(2)
Maize–sugarbeet–cheena	64	(4)[6]	60	(2)	84	(3)
Soybean–wheat+sugarcane–maize[3,4]	53	(8)	51	(8)	80	(4)
Maize–lahi–wheat	54	(6)	54	(5)	79	(5)
Rice–pea–maize	81	(2)[5]	58	(3)	73	(6)
Rice–wheat–gram	54	(6)	54	(4)	68	(7)
Maize–lahi–sugarcane+maize –sugarcane ratoon–maize[4]	57	(5)	48	(9)	66	(8)
Maize–lahi–maize	70	(3)	51	(7)	56	(9)
Rice–gram–cheena	55	(7)	45	(10)	53	(10)

[1] Number of man units required per hectare per year.
[2] Average annual net returns.
[3] Adoption on wide scale depends on possibilities of increasing soybean market.
[4] Two-year rotations. Recent increase in sugar prices responsible for higher degree of profitability than would have been true in past.
[5] High but fairly uniformly distributed.
[6] High and concentrated.

Source:—*New Intensive-Cropping Rotations in Tari,* U. P. Agricultural University, Experiment Station, January 1968, pp. 17, 44-47.

would be influenced by the availability of labor and capital and soil type. While labor requirements are quite high in many of the rotations, they are generally uniformly distributed over the different seasons.[47]

Quadruple cropping is not common, but research carried out by the Indian Agricultural Research Institute showed that it is possible to carry out such rotations utilizing only the same amount of fertilizer recommended for a double cropping sequence of corn and wheat. The tested rotation involved: (1) a legume (such as moong) which is grown on residual fertility, (2) a cereal crop (such as corn) which gets the advantage of the preceding legume and which is also fertilized, (3) a second grain (such as wheat) which is also fertilized, and (4) an oil seed (such as toria) or potatoes.[48] A slight variation

[47] *New Intensive-Cropping Rotations in Tari,* U. P. Agricultural University, Experiment Station, January 1968, pp. 2, 12, 17, 49. More limited financial data on other rotations in India are reported in *Indian Farming,* October 1970.
[48] Gandhi, *op. cit.,* p. 99.

of this rotation is finding favor in the New Delhi area: moong–maize–potato–wheat.[49] Yet another rotation is jowar–jowar(ratoon)–radish–wheat.[50]

Numerous other current multiple cropping rotations have recently been reported in a special issue of *Indian Farming:* "Accent on Multiple Cropping" (October 1970).

INDONESIA

Indonesia is composed of a number of islands, the most important of which is Java. The type of agriculture practiced on Java (and its close neighbor Madura) is much more intense than that followed in the outer islands. Hence most of the multiple cropping is found on Java, although a limited amount of multiple cropping is carried out elsewhere.[51]

It is not known how long multiple cropping has been practiced on Java, but it appears to have increased with the growth of population after 1900. Rice, the basic crop, was double cropped on paddy or watered fields and joined by other crops in the dry areas.[52]

Just what the current multiple cropped area and indexes are, is uncertain. One set of data for the period from 1955 to 1964 show suspiciously wide variations from year to year (Table 21). Still, one might settle for a rough average of 4 million acres and an index of 120 or so.

How do other estimates compare? Jacoby reports indexes of 131 in 1926 and 142 in 1936 for Java, but these seem high on an island-wide basis.[53] *The Asian Agricultural Survey* indicates that in 1962 no more than 2.16 million acres or less than 25% of the 8.65 million acres of rice land were planted to a second crop of rice.[54] Corn and sorghum are commonly planted as a second crop where dry season irrigation is not adequate. Other off-season crops also include peanuts, soybeans, beans, fruits and vegetables, and cassava.[55] The area of these also planted during the dry season has not been reported separately.

Whatever the actual multiple cropping level, it has probably not changed much since 1962.[56] The lack of water seems to be one of the big handicaps. In many parts of Java there just isn't enough water for year-round cultivation,

[49] S. S. Bains and K. S. Randhawa, "Multiple Cropping Pays in Delhi Union Territory," *Indian Farming,* October 1970, pp. 27-28.

[50] Mahendra Pal and S. K. Kaushik, "Multiple Cropping Multiplies Profits," *Indian Farming,* May 1969, pp. 29-30.

[51] Penny found multiple cropping practiced in three of eight villages surveyed in North Sumatra in the spring of 1962; the cropping indexes for the three were 102, 103, and 144 (David H. Penny, "The Transition from Subsistence to Commercial Family Farming in North Sumatra," Cornell University, Ph.D. dissertation, June 1964, p. 89).

[52] Clifford Geertz, *Agricultural Involution: The Process of Ecological Change in Indonesia,* University of California Press, 1963, p. 96 (citing the Dutch agronomist Tergast); D. H. Grist, *Rice,* Longmans, London, 1959 (3rd edition), p. 136.

[53] E. H. Jacoby, *Agrarian Unrest in Southeast Asia,* Columbia University Press, 1949 (1st edition), p. 38.

[54] Yamada and Lusanandana, *op cit.,* p. 26.

[55] Letter from John Shotwell, Agriculture Marketing Advisor, US/AID, Djakarta, August 21, 1970.

[56] *Ibid.*

Table 21.—Multiple Cropped Area and Indexes: Indonesia (Java and Madura)

Year	Multiple Cropped	
	Area	Index[1]
	(1,000 acres)	
1955	828	104.0
1956	2,100	110.3
1957	2,209	110.7
1958	4,314	121.4
1959	3,222	115.3
1960	4,040	119.6
1961	2,585	112.3
1962	4,359	121.6
1963[2]	1,584	107.6
1964[2]	5,248	126.2

[1] Total harvested area as per cent of arable land.
[2] Preliminary.

Source:—Nugroho, *Indonesia Facts and Figures*, Terbitan Pertjobaan, Djakarta, 1967, pp. 237-238.

although efforts are being made to put the land to better use.[57] The World Bank and the Asian Development Bank are making funds available for rehabilitation and construction of irrigation works.[58]

Still, the population is already so dense in some regions that, as Penny puts it, "all the irrigation in the world won't make the people prosperous." He reports visiting an irrigated village in the Jogjakarta area of middle Java, where nearly all the residents depend on agriculture, where the population density has reached the incredible level of 4,600 persons per square mile![59]

IRAN

An unknown amount of multiple cropping is practiced in the Caspian area and the south of Iran in Khuzistan. The leading rotation is composed of grain or summer crops followed by sesame; other rotations include wheat or barley followed by rice, and leafy vegetables followed by summer crops. The leading summer crops are melons, watermelons, tomatoes, and recently, cotton.[60]

As part of a broad development program, the Development and Resources Corporation in California has proposed four alternate cropping patterns for large-scale agricultural enterprises in Khuzistan. An intensive rotation, which

[57] Letters from David H. Penny, The Research School of Pacific Studies, The Australian National University, Canberra, November 13, 1970, March 16, 1971.

[58] *World Bank, International Development Association, Annual Report 1970*, p. 10; *Asian Development Bank, Annual Report for 1970*, pp. 29-30.

[59] Penny, *op. cit.* (1970-71).

[60] Letters from C. S. Stephanides, Agricultural Attache, American Embassy, Tehran, August 18 and September 3, 1970.

has a cropping index of 160, includes grains, vegetables, sugar beets, and beans. It is fully mechanized.[61]

IRAQ

Despite the fact that the Tigris-Euphrates River area was one of the early homes of perennial irrigation and multiple cropping, very little information seems to be available. One review of agriculture in Iraq suggested that the double cropped area in 1958/59 might have been around 60,000 acres, a good part of which was probably vegetables.[62] Another work indicates that pumps are increasingly being used to provide a year-round supply of water; they enable barley, millet and wheat to be grown in the winter and rice in the summer.[63]

JAPAN

Japan's climate largely determines the multiple cropping patterns followed. This is depicted in Figure 3. It will be noted that double cropping was limited essentially to the lower half of the nation in the early 1930's; the limits may have moved north somewhat since then. Most of the double cropped area is suited only to summer rice and a "dry" winter crop such as wheat or barley. Only a very small portion is suitable for two crops of rice. The multiple cropping index increases as one goes south.[64]

Japan is one of the few countries in the world to show a declining index of multiple cropping (Table 22). The decline is principally due to a drop in the area planted to dry winter crops. The area of rice double cropping has held about steady. Opinions vary as to the reason for the decline. Barse suggests that the area of dry winter crops has dropped off because of two major factors: (1) a decrease of farm labor availability due to shifts to other employment or to retirement, and (2) low returns, especially from barley.[65] Sawada thinks that the decrease in double cropping was due to the growing import of grains.[66]

Only about 26,000 acres or less than one percent of the total multiple cropped area was planted to two crops of rice during the 1960 to 1969 period.

[61] Letters from John Freivalds, Economist, Development and Resources Corporation, Sacramento, September 9, October 26, 1970. The development project is described by Lee Griggs in "Oil and Water Rebuild an Ancient Land," *Fortune,* November 1970, pp. 90-96.

[62] H. Charles Treakle, *The Agricultural Economy of Iraq,* U.S. Department of Agriculture, Economic Research Service, ERS-Foreign 125, August 1965, p. 30.

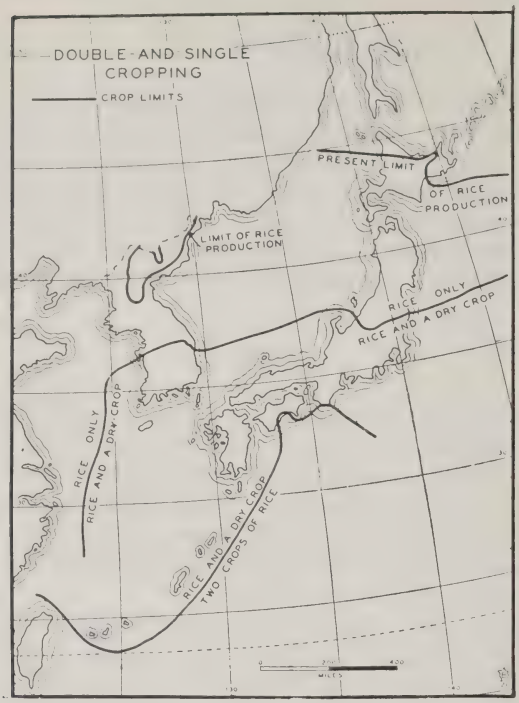
[63] Leonard M. Cantor, *A World Geography of Irrigation,* Praeger, 1970, p. 136.

[64] Takane Matsuo, *Rice and Rice Cultivation in Japan,* Institute of Asian Economic Affairs, Tokyo, 1961, p. 81.

[65] Joseph R. Barse: *Japan's Food Demand and 1985 Grain Import Prospects,* U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 53, June 1969, p. 41; "Changed Rice Policies Could Transform Japan's Farming", *Foreign Agriculture,* February 9, 1970, p. 5.

[66] Shujiro Sawada, "Technological Change in Japanese Agriculture: A Long-Term Analysis," in *Agriculture and Economic Growth: Japan's Experience* (ed. by Ohkawa, et al.), Princeton University Press/University of Tokyo Press, 1969, p. 152.

Figure 3. Northern Limits of Cropping Systems
Japan



Source: Robert B. Hall, "The Japanese Empire," *Economic Geography*, October 1934, p. 339.

Nearly all of this is found in Kagoshima, Kochi, and Miyazaki perfectures.[67] As noted earlier, the practice originated in Kochi several hundred years ago and reached a peak in 1932; it declined thereafter due to pest and disease damage and a shortage of labor. After World War II the area began to expand modestly: the introduction of high-yielding varieties brought about its spread to Kagoshima and Miyazaki.[68]

KOREA (South)[69]

Double cropping is extensively utilized in South Korea. During the 1960's the index for the nation averaged about 152, with no clear trend (Table 23). Of the total double cropped area in 1969, about 52% was paddy land and 48% upland fields (the paddy proportion increased during the 1960's, while the

[67] Calculated from official data provided by Dr. Yujiro Hayami, Faculty of Economics, Tokyo Metropolitan University, September 3, 25, 1970.

[68] Matsuo, *op cit.*, pp. 81, 177. Also T. Matsuo, *Rice Culture in Japan*, Yokendo, Ltd., Tokyo, 1955, pp. 28, 37.

[69] William Gasser of the Economic Research Service was of assistance in the preparation of this section.

Table 22.—Multiple Cropped Area and Indexes, Japan
(Includes Green Manure Crops)

Year	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1950	6,336	152
1952	5,747	144
1956	6,246	144
1957	6,020	143
1958	5,910	142
1959	5,654	140
1960	5,755	140
1961	5,565	139
1962	5,525	139
1963	5,112	136
1964	4,678	133
1965	4,300	131
1966	4,030	129
1967	3,672	126

Sources:—Annual reports of the Ministry of Agriculture and Forestry: *Statistical Yearbook;* and *Abstract of Statistics on Agriculture, Forestry and Fisheries.*

Table 23.—Multiple Cropped Area and Indexes, South Korea

Year	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1960	2,328	146.1
1961	2,556	150.5
1962	2,590	150.4
1963	2,673	151.6
1964	2,911	153.8
1965	3,243	157.7
1966	2,890	150.6
1967	2,990	151.9
1968	3,001	151.9
1969	3,074	153.4

Source:—Computed from data in *Yearbook of Agricultural and Forestry Statistics,* Ministry of Agriculture and Forestry, Seoul, 1970, pp. 66, 76.

upland proportion declined). Of the total paddy land in 1969, about 50% was double cropped; the similar portion for upland was about 58% (again the paddy proportion increased during the 1960's and the upland portion declined).

As elsewhere, there are considerable geographic variations. Overall, most of the double cropping is concentrated in the central and southern portions of the country because of climatic and soil conditions. Paddy and upland fields, however, show quite different patterns. Most of the double cropping on paddy land is concentrated in the south, while upland double cropping shows a much more uniform distribution.[70]

The major off-season crop is barley. According to one survey in the mid-1960's, barley made up 89% of the total double cropped area; wheat accounted for 5%. Rye was grown on the poorer lands. In the North, the second crop was largely devoted to feed crops.[71]

Despite weather constraints, it is felt that more double cropping could be carried out. The reason, according to Shim, is economic; double cropping just doesn't pay the farmer enough. Both yields and prices are low. The potential for improving the situation as reported by Gasser, et al., varies by crops:[72]

- Barley. There are very good prospects for improving the yield of barley through better cultural practices including liming, varietal improvement, and more favorable price-cost relationships. Although demand for barley as a food will decrease as the standard of living rises, there are real possibilities for use as a livestock feed. Despite this potential, relatively little research is being done.
- Wheat. Considerable research has been done on wheat as a second crop. The main problem at present is that the growing season is about two weeks longer than for barley. Emphasis is being placed on breeding earlier-maturing varieties.
- Rice. The growing season is too short to readily grow a second crop. It is technically possible to grow two crops (by setting out seedlings under vinyl hot beds) but, because of the limited growing season, yields of both are reduced.

Finding or developing a crop which can both achieve high yields and be in strong demand will be a considerable challenge. In addition it may be necessary to give attention to mechanization to shorten the "turn around" time in the spring and fall. Irrigation and drainage continually need improvement.

LAOS

Until recently, multiple cropping was practiced to only a very limited extent in Laos. A change occurred during 1966/67 with the introduction of the

[70] Jin Hwan Park, *An Economic Analysis of Land Development Activities in Korea, with Special Reference to Upland Development Programs in 1962-1967*, Seoul National University, Department of Agricultural Economics, November 1969, pp. 10, 86.

[71] Young Kun Shim, *Economic Analysis of Double Cropping in Paddy Fields*, Seoul National University, College of Agriculture, Code No. 66-26, 1967 (distributed in 1969), pp. 5, 26. Shim's survey of 1,258 farms also indicated a lower proportion of paddy land double cropped in 1967 (33%) than did the official figures (47%).

[72] William R. Gasser, et al., *Planning Korea's Development: Analyses and Recommendations for the Third Five Year Plan*, U.S. Department of Agriculture, Foreign Economic Development Service, FEDS Field Report 5, August 1970, pp. 23-27.

new short-season rice varieties from the International Rice Research Institute. Nearly all the second crop farming since then has been rice grown under irrigation during the dry season. Areas so planted are estimated as follows:[73]

Year	*Area* (acres)
1967/68	2,390
1968/69	4,440
1969/70	3,100
1970/71	3,580

Emphasis is now shifting from rice to other crops such as corn, sorghum, soybeans, and peanuts.

A number of projects are underway which will extend the irrigated area during both the wet and dry seasons. In March 1970, the Asian Development Bank approved a loan to the Laotian Government which will enable it to transform about 2,000 acres of unused land in the northern part of the Vientiane Plain into year-round irrigated farming. Both rice and vegetables are to be produced.[74]

The rather relaxed attitude of some Laotian farmers towards such intensive activities has already been noted in Chapter III. In addition, it is reported that some farmers are not interested in dry season rice because they feel it will leave them or their buffalo too tired to work efficiently the following wet season.[75] There are, however, other factors which limit adoption: (1) many of the young men have been inducted into the military service, leaving only the old men, women, and children to do the farming; (2) internal transportation is poorly developed. Since many of the Laotian centers of population are just across the Mekong River from Thailand, which has a relatively good road system, more food is imported than would otherwise be the case.[76]

LEBANON

Although Lebanon is one of the most densely populated nations in the world in terms of agricultural land per capita, multiple cropping is very limited. The U.S. agricultural attache in Lebanon estimates that out of approximately 178,000 irrigated cultivated acres, only about 2,600 (or roughly 1.5%) are multiple cropped. Of the multiple cropped area, practically all is double cropped; only about 124 acres are triple cropped. The three areas where multiple cropping is found are the North Coast (mainly the Akkar Plain), the Central and South Coast, and the Central Beka'a Valley. In nearly every case the rotations are built around vegetables; on the North Coast the rotation

[73] Letter from Donald R. Mitchell, Deputy Chief, Agriculture, US/AID Mission to Laos, Vientiane, April 23, 1971. A recent Asian Development Bank report placed the figures slightly higher: 1967/68, 3,700 acres; 1968/1969, 5,000 acres (of which 1,100 were in the Vientiane Plain).

[74] "ADB Approves Loan and Technical Assistance for the Tha Ngon Project in Laos," Asian Development Bank, Manila, News Release No. 3/70, March 10, 1970.

[75] T. L. Jones et. al., *An Evaluation of the Agricultural Development Organization of Laos*, Ohio State University, Department of Agricultural Economics, AFC Research Publication 130, 1969, p. 41.

[76] Mitchell: *op. cit.*; letter, June 1, 1971.

involves early potatoes (harvested in June) and late peanuts (harvested in late October and November).[77]

MALAYSIA

Two quite different cropping systems are found in the two major portions of Malaysia. West Malaysia (on the Malay Peninsula) follows a traditional paddy field system, whereas a slash and burn system is found in East Malaysia (Sabah and Sarawak). Thus agriculture is much more modern and yields correspondingly higher in the West than in the East. In both cases, rice is the staple food.[78]

West Malaysia

The statistics on multiple cropping in West Malaysia are limited to the rice area double cropped. Still, they probably reflect nearly all the multiple cropped area.

The area of rice land reportedly double cropped has expanded very sharply since the middle 1950's: from 6,400 acres in 1956/57 to 238,000 in 1969/70. Two sets of estimates by years are reported in Table 24. The figures are very close for the five year overlap period.

Off-season rice plantings were begun by Chinese farmers in Province Wellesley on the northwest coast during the Japanese occupation in the mid-1940's when food was in short supply.[79] Some 30,000 acres were double cropped in Province Wellesley in 1969. A further 22,000 acres were found at Tanjong Karang at Selangor and another 10,000 acres in the Kedal plain (where experimental trials were started "some years back").[80]

The recent and projected expansion in area is tied in with the development of several irrigation schemes. The Sungei Muda project will enable farmers in the principal rice bowl in the states of Kedah and Perlis (on the northwest coast) to grow a second crop on 130,000 acres in 1970, 234,000 in 1971, and 261,000 in 1972. To the south, the Kemubu scheme will make it possible to double crop another 47,000 acres.[81]

Early maturing rice varieties are expected to play a major role in making double cropping possible. The extent to which crops other than rice will be planted is uncertain. A comparison of the single and double cropping patterns in the Muda Project is provided in Figure 4.

The Asian Development Bank has recently provided a loan of $4.2 million to provide irrigation to make double cropping possible on 12,600 acres of

[77] Letter from William Horbaly, Agricultural Attache, American Embassy, Beirut, April 16, 1971.

[78] Foreign Agricultural Service Report No. MY 9035 from Kuala Lumpur, October 31, 1969, p. 2.

[79] Letter from Dale K. Vining, Agricultural Attache, American Embassy, Kuala Lumpur, March 12, 1971.

[80] "Muda River Project," *World Crops*, March/April 1969, p. 14.

[81] Dale K. Vining, "West Malaysia's Rice Irrigation Project," *Foreign Agriculture*, July 14, 1969, pp. 9-10; Foreign Agricultural Service Report No. MY0015 from Kuala Lumpur, September 17, 1970.

Table 24.—Estimated Rice Area Double Cropped, West Malaysia

Season	Estimate	
	AAS[1]	FAS[2]
	—thousands of acres—	
1956/57	6.4	
1957/58	7.2	
1958/59	10.4	
1959/60	20.0	
1960/61	35.1	
1961/62	46.0	47
1962/63	48.7	49
1963/64	57.8	58
1964/65	88.7	90
1965/66	103.3	104
1966/67		157
1967/68		225
1968/69		238

Notes:

[1] Rice double-cropping area.

[2] Planted to off-season rice crops. The harvested area was usually about one thousand less.

Sources:—

AAS. Noboru Yamada and Bhakdi Lusanandana, "Rice Production in the ADB Region," in *Asian Agricultural Survey,* Vol. II, March 1968, p. 30.

FAS. Foreign Agricultural Service Report No. MY0009 from Kuala Lumpur, May 8, 1970 (Enclosure 1, pp. 1-2).

paddy fields in the state of Trengganu. Total cost of the project is expected to be $7.1 million.[82]

East Malaysia

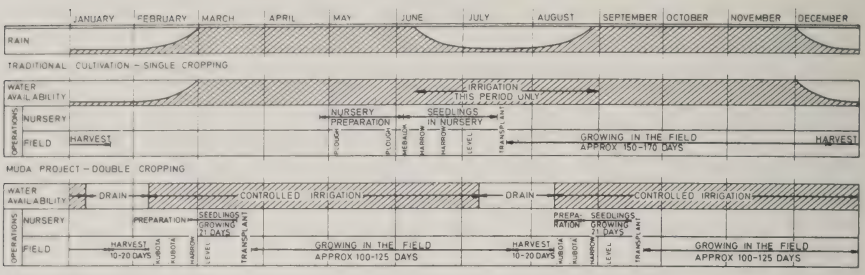
Double cropping has been very limited in Sabah and Sarawak for several reasons: rubber has been considered a more profitable crop than rice, the population is relatively small, and there has been an absence of any real hunger. Recent government policy has been to increase the level of local rice production and this, together with a scarcity of good fertile land, has led to interest in growing a second crop of rice.[83] Experimental work done at the Tuaran Agricultural Research Station in Sabah showed that double cropping was possible. In 1968 an estimated 4,000 acres produced two crops.[84]

[82] "International Letter," National Association of Land Grant Colleges and Universities, No. 67, December 29, 1970, pp. 11-12.

[83] Kieran Broadbent, "Case for Irrigation," *Far Eastern Economic Review,* December 26, 1968, p. 738.

[84] Department of State Airgram A-3 from Kuching, January 10, 1969.

Figure 4. Traditional Cultivation Compared with Multiple Cropping, Muda Project, West Malaysia



Source:—"Muda River Project," *World Crops*, March/April 1969, p. 13.

MEXICO

The extension of multiple cropping is a relatively new development in Mexico. The 1950 Census of Agriculture indicated that only about 100,000 acres were multiple cropped. By 1960, the area appears to have increased to nearly one million acres, or nearly 3% of the total cultivated area.[85]

Most of the multiple cropped area is on irrigated land. In 1968-69, out of a total of 4,319,000 acres of irrigated land, 1,074,000 (or slightly more than indicated in the 1960 census) were reportedly multiple cropped, providing a cropping index of 124.9. The areas multiple cropped in each of the six major regions are indicated in Table 25. Together, the two Pacific North states

Table 25.—Distribution of Double Cropped Area in Six Leading States, Mexico, 1968-69.

State	Region	Double Cropped	
		Area	Index
		(acres)	
Sonora	Pacific North	398,100	151.3
Sinaloa	Pacific North	216,000	129.4
Guanajuato	Central	163,500	201.3
Michoacan	Central	90,800	136.9
Tamaulipas	North	65,800	109.9
Chihuahua	North	56,800	128.6

Source:—Compiled from *Superficies Regadas y Volumenes de Aqua Distribuidos en Los Distritos de Riego en el Ciclo Agricola 1968-69*, Secretaria de Recursos Hidraulicos, Informe Estadistico No. 49, July 1970, pp. 157-158.

[85] Reed Hertford, "Sources of Change in Mexican Agricultural Production," U.S. Department of Agriculture, Economic Research Service, unpublished manuscript, August 1969, pp. 56, 58; *IV Censo Agricola–Ganadero y Eidal, 1960*, p. 140.

accounted for about 57% of the double cropped area on irrigated land; the highest index, however, was in Guanajuato in the Central region.[86]

Some double cropping is also carried out on nonirrigated land which has sufficient natural rainfall. This is most apt to be found in the Pacific South region. According to one researcher, there has been a large increase in the double cropped area in these regions. Contributing factors included seasonal employment of labor and few off-farm employment opportunities.[87]

NIGERIA

Several variations of multiple cropping are practiced in Nigeria. These center about what we identified earlier in this report as relay interplanting.

Recently some interesting cropping experiments have been carried out at Samaru.[88] The purpose of the tests was initially to see if it would be possible to achieve a higher return per acre from two successive cereal crops than from one long season dwarf sorghum crop. The results obtained at Samaru in 1968 are summarized as follows:

Cropping Pattern	*Gross Return* (shillings per acre)
Single Cropping	
Hybrid sorghum*	656
Double Cropping	
Millet–cowpeas	830
Maize–cowpeas	1074

*3 X 2 dwarf Samaru Hybrid No. 2

Gross returns from the millet-cowpea rotation were 26.5% higher than the single crop of hybrid sorghum; those for the maize-cowpea rotation were 63.7% higher. Net returns were not reported.

Despite the potential for higher returns, two major constraints limit farmer use of the double crops: (1) the process involves "extensive cultivations which he cannot perform with his limited resources," and (2) the sole crops (relative to intercropping) involve risk factors which ". . . are presently unacceptable to the subsistence farmer."

To help get around these problems, another variation was subsequently tried in 1969; the sorghum was interplanted with preceding double cropping combinations.[89] The results were even more promising in terms of gross returns:

[86] Compiled from *Superficies Regadas y Volumenes de Agua Distribuidos en Los Distritos de Riego en el Ciclo Agricola 1968-69*, Secretaria de Recursos Hidraulicos, Informe Estadistico No. 49, July 1970, pp. 157-158. (Kindly provided by Roger Norton of the World Bank.)

[87] Hertford, *op. cit.*

[88] D. J. Andrews, "Relay and Intercropping With Sorghum at Samaru," Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria, November 1970. D. W. Norman of the same institution has studied intercropping economics at the village level.

[89] That is, one row was planted to sorghums while the next row was planted to either millet or maize early in the season followed by cowpeas later in the season. Rows were used to allow mechanization.

Cropping Pattern	*Gross Return* (shillings per acre)
Single Cropping	
Hybrid sorghum	513
Double Cropping/Interplanting	
(a) Hybrid sorghum	
Maize—cowpeas	874
(b) Hybrid sorghum	
Millet—cowpeas	1020

The returns for combination (a) were 70.4% higher than for single cropping, while those for (b) were 98.8% greater. The greater returns were possible because the sorghum offered little competition to the early cereals, whereas the cowpeas apparently had little effect on the sorghums. In addition, neither cereal lodged as much as if grown alone and fewer weeds than expected grew in the interplanted cowpea crop. Further tests conducted in 1970 confirmed these findings.[90]

The combinations are on the definitional margin between multiple cropping and intercropping but obviously provide an alternative which is worthy of further investigation in other areas.

NEPAL

The southern edge of Nepal, known as the Terai, is part of the Ganges Plain and is intensively cropped. Double cropping is practiced, and in the areas where good irrigation facilities are available, triple cropping is carried out. Rice is the major monsoon season crop, while wheat and some pulses are planted during the winter period. Winter crops are grown on only about ¼ of the rice and jute land in the Terai and not all of this may represent multiple cropping. In the Inner Terai, mustard is double cropped with rice or corn. A rice—wheat rotation is also used in the midlands (Mahabharat sector). On the high terraces a rotation of maize followed by millet is the common practice. In the higher altitudes, short-term barley may be followed by buckwheat.[91]

PAKISTAN

Physically, East and West Pakistan are quite different. East Pakistan is a low-lying, relatively wet region where rice is by far the main crop. West Pakistan is a relatively arid area which has wheat as a main crop. The population density is much greater in the East than in the West.

The Indexes

For these reasons, one might expect a much higher multiple cropping index in the East than in the West. Such is the case. As may be seen in Table 26, which is based on official data, the index in the East in recent years has averaged about 138, while that in the West has been about 112.

[90] Letter from Andrews, April 6, 1971.

[91] "Country Progress Report: Nepal," *7th NESA Irrigation Practices Seminar*, US/AID, Lahore, 1968, pp. 68, 71; letter from Raymond E. Fort, Chief, Food and Agriculture Division, US/AID, Kathmandu, March 10, 1971.

Table 26.—Multiple Cropped Areas and Indexes, East and West Pakistan

Season	East Pakistan		West Pakistan	
	Multiple Cropped[1]		Multiple Cropped[1]	
	Area	Index	Area	Index
	(1,000 acres)		(1,000 acres)	
1949-50	5,564	127.6		
1950-51	5,708	127.8	3,131	111.1
1951-52	6,080	129.4	2,333	108.4
1952-53	6,574	131.4	2,066	107.4
1953-54	6,909	133.1	2,825	109.4
1954-55	6,572	131.4	3,503	112.0
1955-56	5,509	126.9	3,875	112.7
1956-57	5,468	126.7	3,774	112.1
1957-58	5,620	127.7	2,405	111.0
1958-59	5,366	127.0	4,520	114.3
1959-60	5,902	128.7	3,105	109.6
1960-61	6,732	132.3	2,421	107.5
1961-62	6,453	130.8	3,447	110.4
1962-63	6,796	132.5	3,187	109.4
1963-64	7,095	133.7	4,191	112.9
1964-65	7,434	135.2	5,140	114.7
1965-66	7,940	136.8	4,473	112.9
1966-67	7,926	137.6	4,116	111.7
1967-68	9,694	144.6	3,046	108.5
1968-69	8,479	139.2		

[1] Area sown more than once during one season (see discussion in text).

Sources:—

E. P. *East Pakistan Agriculture, 1968-69,* USAID, Dacca (enclosure to FAS Report PK 0064, September 8, 1970).

W. P. 1949-50 to 1965-66. *Pakistan Statistical Yearbook, 1967,* Central Statistical Office, Karachi, 1968, p. 76.

1966-67 to 1967-68. Official data provided by Jerry B. Eckert, The Ford Foundation, Lahore, November 6, 1970.

The precise index figures, however, are suspect on several counts. Since the population density in East Pakistan is one of the highest in the world, it is surprising that the index is not larger.[92] Part of the answer may be that much of the cropland is flooded part of the year (though this may enhance cropping

[92] The indexes as reported in some other studies varied from those reported here. Generally they were higher. Data reported by Ahmad indicate an index of 139 in 1944-45 (*An Economic Geography of East Pakistan.* Oxford University Press, Karachi, 1958, p. 168). In a survey of 711 cultivators in 1958-59, the cropping index was reported to average 133.9 (*Survey Report on Cropping Patterns in Selected Districts of Pakistan,* Ministry of Food and Agriculture, Department of Agricultural Economics and Statistics, Rawalpindi, Survey Series 2, February 1962, p. 7). Data used by Revelle and Thomas suggest an average index of 144 from 1960-65 ("Population and Food in East Pakistan," Harvard Center for Population Studies, Fall 1969, Table 1). Cantor, without mentioning a specific year, also suggests an index of 143 (*A World Geography of Irrigation,* Praeger, 1970, p. 128). On the other hand, statistics provided in a master plan for the East Pakistan Water and Power Development Authority show indexes 1 to 3 points lower for the 1948-49 to 1956-57 period (Master Plan, International Engineering Co., San Francisco, Supplement B, December 1964, p. IV/3), while another source suggests that double cropping is carried out on 25% of the land and triple cropping on 5% ("Country Progress Report: Pakistan," *8th NESA Irrigation Practices Seminar,* US/AID, Kabul, 1970, p. 67).

the rest of the year), and the country is extremely poor and has not yet had the resources—technical and financial—to develop off season production to its maximum level. Still, the trend seems to be very gradually upward.

No special trend was apparent in the West through 1963/64; since 1964/65, however, the area seems to have decreased. The recent decline, even assuming that 1964/65 was an unusual year, is most difficult to understand because there has been a sharp increase in the use of tubewells and early maturing varieties of wheat and rice during this period. Farm management studies, in fact, reveal that in Tehsils of Peshawar and Nowshera where adequate water was available, the intensity of cropping increased from 1964-65 to 1968-69; in irrigated regions in Rawalpindi and Multan additional area was put in vegetables.[93]

Subsequent investigations have revealed that the official figures for West and presumably East Pakistan are, in fact, in error. It seems that the data reflect the amount of multiple cropping reported in each of two inspections during the year; thus the amount of double cropping reported refers only to one season and not the year. Hence the amount of double cropping is sharply underreported. The problem is particularly severe in West Pakistan where wheat has been replacing two shorter season crops in recent years, thus bringing about a decline in the reported cropping intensity, if not in land use intensity. The government subsequently began to recalculate the data for the past four years; preliminary tabulations show sharp differences.[94]

East Pakistan

In many ways, as suggested, East Pakistan is a most appropriate area for multiple cropping. The climate generally permits a wide range of crops to be grown year round. The main problem is water control; much of the area is flooded in the wet season and irrigation is needed in the dry season. As progress is made in these and other areas such as research and the provision of capital, the index of multiple cropping may be expected to increase.

There are basically three growing seasons available during the year in East Pakistan. Paddy rice occupies about 95% of the total cropped area and in many places is reportedly harvested in each of the three seasons.[95] The amount planted is least during the winter or boro season because of limited rainfall. Still, other crops with lower water requirements could be planted during this period, and more rice could be planted if irrigation were available.

The installation of tubewells began in the Comilla area in East Pakistan in 1962 with the intention of promoting winter planting of a third crop. By 1964-65, the project sponsors were experiencing difficulty because the farmers "showed a lack of knowledge about . . . the profitability of winter cropping by

[93] "Survey Report on Spread of New Agricultural Technology to Small Farms in Pakistan," *Farm Management Research in Pakistan* (Ministry of Agriculture and Works, Planning Unit), October 1969, p. 14.

[94] Letters from Jerry B. Eckert, Agricultural Planning Advisor, The Ford Foundation, Lahore, March 1, 1971, April 28, 1971.

[95] *Survey Report on Cropping Pattern and Crop Intensities in Selected Districts of Pakistan,* Ministry of Food and Agriculture, Department of Agricultural Economics and Statistics, Rawalpindi, Survey Series 2, February 1962, p. 3.

means of tubewell." Cost and return studies were carried out on the 1965-66 crop and showed that the growers taking to winter irrigation and cropping were earning a "handsome profit"[96] By 1969 a total of 11,400 pumps had been installed in the Comilla District, and during 1970 the figure was expected to rise to 18,000. More than 500,000 new irrigated acres were under cultivation, over a third of which was devoted to IR-8 rice.[97]

West Pakistan

Because of its dryer climate, irrigation has been of even more importance in the growth of multiple cropping in West Pakistan. This close relation was suggested in a study in 1962.[98] The type of irrigation, moreover, is of further significance; a survey in the Punjab the winter of 1967 indicated that the cropping intensity for growers of cotton and rice using canal irrigation was only 90, while that for tubewell farmers was 135.[99]

Both studies, as well as the 1960 census, also suggested an inverse relationship between farm size and cropping intensity. This disparity, however, was reported to decrease in the Punjab with the installation of tubewells; they appeared to raise the cropping intensity of the larger farms proportionally more than the smaller farms.[100]

PHILIPPINES

Multiple cropping data for the Philippines are not entirely clear or consistent. On the one hand, statistics reported in the Census of Agriculture suggest the following multiple cropped areas and indexes (some intercropping may be included)[101]:

Year	*Multiple Cropped*	
	Area (1,000 acres)	*Index*
1938	2,607	127
1948	2,357	126
1960	4,982	136

[96] Mahmoodur Rahman, *Costs and Returns: Economics of Winter Irrigated Crops in Comilla, 1965-66,* Comilla, March 1967, pp. 1, 2, 125. Also see A. F. Raper, *Rural Development in Action,* Cornell University Press, 1970, pp. 139-152, 215.

[97] Nicolaas Luykx, ". . . Rural East Pakistan," in *Some Issues Emerging from Recent Breakthroughs in Food Production* (ed. by K. L. Turk), Cornell University, 1971, pp. 162-163.

[98] *Survey Report . . . op. cit.* (1962), pp. 18, 21. Also see *Water and Power Resources of West Pakistan,* Vol. II, Johns Hopkins Press, 1969, pp. 52-58.

[99] Hiromitsu Kaneda and Mohammed Ghaffar, "Output Effects of Tubewells on the Agriculture of the Punjab: Some Empirical Results," *Pakistan Development Review,* Spring 1970, p. 71.

[100] *Ibid.,* pp. 71-73.

[101] *Census of Agriculture 1960,* Bureau of Census and Statistics, Manila (as reported by Cristina Crisostomo, et al., "The New Rice Technology and Labor Absorption in Philippine Agriculture," in *Rice Policy Conference: Current Papers from the Department of Agricultural Economics,* International Rice Research Institute, May 9-14, 1971, p. 15, Table 8).

On the other hand, partial data from other sources suggest considerably lower figures. Jacoby notes that in 1938 a total of nearly 580,000 acres of rice and corn were planted more than once; writing in the late 1940's he placed the double cropped area at 6 to 8% of the total crop area.[102] Elsewhere it has been estimated that about 1.235 million acres of rice, or approximately 15% of the total rice area, were double cropped in 1965.[103]

Survey data from the 1950's and 1960's, while not exactly comparable, tend to confirm the general cropping index level reported for 1960. A survey of 5,179 farms in 1954/55 revealed that 34% of the cropland was double and/or intercropped (ranging from 21% to 67% between regions); of the 3,801 farmers in this group who were classified as lowland rice farms, 33% planted a second crop (19% rice, 14% other).[104] Another survey carried out among 292 lowland farms in 1962/63 showed an index of about 148 (approximately 20% of the farmers raised a second crop of rice while the rest planted other second crops).[105] A third survey of 50 farms conducted in 1968-69 revealed an index ranging from 100 to 213, depending on the type and size of farm.[106]

In some regions, the cropping indexes are higher for upland than lowland rice farms. This has occurred in Batangas, where it is possible to carry out multiple cropping within the existing rainfall pattern.[107] The irrigation systems in the lowland areas are designed primarily for the production of rice and they lack the controls necessary for the production of most alternative crops.[108]

Most vegetable farms grow three crops a year. On the low land in Laguna, either two crops of tomato or three of cucumber can be raised. In the Baguio area, four crops may occasionally be produced.[109]

[102] E. H. Jacoby, *Agrarian Unrest in Southeast Asia,* Columbia University Press, 1949 (1st edition), p. 177. The 1938 figure was based on a report by Pelzer and is found in fn. 16.

[103] Yamada and Lusanandana, *op. cit.,* p. 26. Another source places the irrigated paddy area under a second crop in 1965/66 as 697,000 acres (Shigeru Ishikawa, *Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand,* Asian Development Bank, Manila, 1970, p. 16).

[104] Horst and Judith von Oppenfeld, et al., *Farm Management, Land Use and Tenancy in the Philippines,* University of the Philippines, Central Experiment Bulletin 1, August 1957, pp. 37, 119 (as cited by Crisostomo, et al., *op. cit.,* p. 16).

[105] E. R. Bernal, "Unit Requirements, Costs and Returns for Producing Palay and Secondary Crops in Central Luzon, 1962-1963," *The Philippine Agriculturist,* September-October 1964, pp. 203-232. This index is particularly high because the farms involved all grew some secondary crops.

[106] Moises L. Sardido, "Income Distribution Patterns of Rice Farms in Bico," International Rice Research Institute (Saturday Seminar), December 1969, Tables 9 & 12 (cited by Crisostomo, et al., *op. cit.,* p. 16, Table A-14).

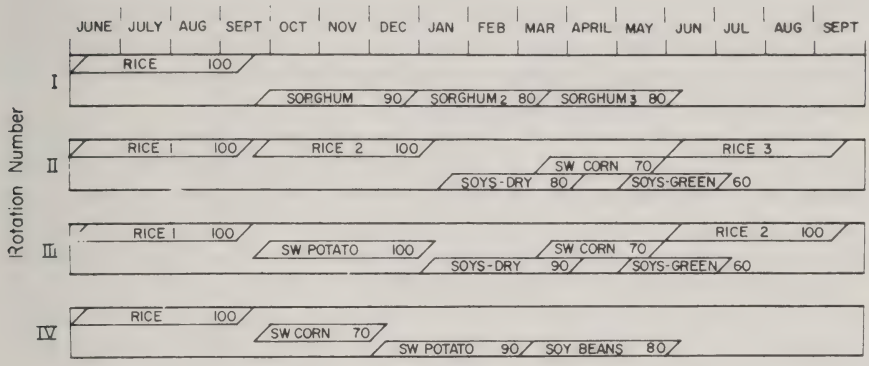
[107] N. R. Deomampo, et al., "The Effects of Cropping Patterns on Farm Capacity," *The Philippine Agriculturist,* June 1969, pp. 17-27; E. M. Gonzales, "The Economics of Crop Diversification on Upland Farms in Balete, Tanauan, Batangas," University of the Philippines, undergraduate thesis, 1969 (as cited by Crisostomo, et al., *op. cit.,* pp. 16, 17).

[108] Crisostomo, et al, *op. cit.,* pp. 17-19.

[109] C. L. Luh, "Report on Vegetable Production Survey in Southeast Asian Countries," Seminar on Food Problems in Asia and the Pacific, Honolulu, May 1970, p. 11.

Some of the most advanced research in the world on multiple cropping has been undertaken by Dr. Richard Bradfield, an agronomist, at the International Rice Research Institute. Utilizing exceptional growing conditions, Dr. Bradfield has developed some very sophisticated rotations, involving the cultivation of five crops a year. Four of the leading combinations, as reported in 1968, are presented in Figure 5.

Figure 5. Multiple Cropping Rotations Tested at IRRI, Philippines



Source:—Richard Bradfield, "Increasing Food Production in the Tropics by Multiple Cropping," in *Research for the World Food Crisis* (ed. by Daniel G. Aldrich Jr.), American Association for the Advancement of Science, Publication No. 92, 1970, p. 242.

According to Bradfield, these sequences give a good distribution of planting and harvesting dates throughout the year. They also make marketing, especially of vegetables which are sold in the fresh state, much simpler. The frequent harvests, Bradfield suggests, give the farmer something to sell regularly and simplify his credit problems.[110]

The cultural conditions for this work at IRRI and the complex nature of the rotations may put them out of the reach of most farmers. But they do provide an idea of the upper limit of what can be accomplished. Hopefully, more reports on this work will be forthcoming. An agricultural economist has recently joined the project and will study the costs and returns from such rotations.

RHODESIA

A limited amount of double cropping is carried out on some irrigated land in Rhodesia. Data for native agriculture, covering about 4,700 acres of irrigated land in 1961 (4,370 of which were in the Sabi Valley in the eastern part and the remainder in the Midlands province) revealed a total cropped area of over 7,000 acres, or a cropping index of at least 160.[111] Similar information has not

[110] Richard Bradfield, "Increasing Food Production in the Tropics by Multiple Cropping," in *Research for the World Food Crisis* (ed. by Daniel G. Aldrich, Jr.), American Association for the Advancement of Science, Publication No. 92, 1970, pp. 229-242.

[111] R. W. M. Johnson, "African Agricultural Development in Southern Rhodesia: 1945-1960," *Food Research Institute Studies*, 1964 (Vol. IV, No. 2), p. 187 (based on

been found for irrigated land in estate agriculture. Recent research on crop rotations in the Sabi Valley has centered on wheat and some beans in the winter and cotton, corn, and soya beans in the summer.[112]

TAIWAN

Multiple cropping has probably reached its highest stage of commercial development in the free world in Taiwan. This development, as we have noted, largely seems to have been a product of the 20th Century. It was not due to any great gift of nature; indeed, the opposite was true. The lack of land and a large population made multiple cropping necessary. The process was initiated when Taiwan was under Japanese rule and was facilitated by the technical and capital improvements made during this period.

Multiple cropping indexes in Taiwan over the past 20 years (Table 27) have been higher than for any nation in the world, though possibly not for certain provinces in Mainland China. The high point, an index of 190, was reached in 1966, and in the subsequent three years the index declined slightly. The recent drop in the index according to Cheng, may be traced to (1) a tightening of the labor market due to rapid industrial development, (2) increased cost of inputs, and (3) increased competition from large scale imports of lower priced soybean, corn, and wheat beginning in 1967 (these imports were made to encourage the development of the local livestock industry).[113]

Within the island, the cropping indexes, as elsewhere, vary considerably by prefecture. In 1960 and 1961 the range was from a low of 132 in Penghu to highs of 232 and 233 in Taichung and Changhua.[114] The differences are quite pronounced between the central and southern portions, as illustrated below:[115]

Year	*Region*		*Country*
	Central	*South*	
1950	212	162	170
1955	213	167	171
1960	234	172	184

A number of cropping systems are followed. Some are summarized in Figures 6 and 7.[116] It can be seen that two crops of rice form the basis for the

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reports of the Director of Native Agriculture). The total area irrigated, which includes estates, was reported to be about 22,000 acres in 1961 (*Production Yearbook, 1965*, FAO, p. 10).

[112] Foreign Agricultural Service Report RH-9121 from Salisbury, September 25, 1969; *Report of the Secretary for Agriculture*, 1969, Salisbury, p. 29 (I am indebted to John Dunmore of ERS for these references).

[113] Chien-pan Cheng, "Multiple Cropping Practiced on Paddy Field in Taiwan," Joint Commission on Rural Reconstruction, Taipei, April 1970, p. 11.

[114] T. H. Lee, "Agricultural Diversification and Development," SEADAG Paper No. 71-2 (The Asia Society, New York), p. 16.

[115] T. H. Shen, *Agricultural Development on Taiwan Since World War II*, Comstock Publishing Associates, 1964, pp. 156-157.

[116] Cropping systems are also summarized in Raymond P. Christensen, *Taiwan's Agricultural Development: Its Relevance for Developing Countries Today*, U.S. Department of Agriculture, Foreign Agricultural Economic Report No. 39, April 1968, p. 50.

Table 27.—Multiple Cropping Area and Indexes, Taiwan

Year	Multiple Cropped	
	Area	Index
	(1,000 acres)	
1950	1,500	169.7
1951	1,505	169.7
1952	1,557	171.9
1953	1,564	172.5
1954	1,594	173.8
1955	1,537	171.3
1956	1,633	175.5
1957	1,705	179.0
1958	1,745	179.9
1959	1,769	181.5
1960	1,794	183.6
1961	1,848	185.8
1962	1,838	185.3
1963	1,826	184.7
1964	1,917	188.0
1965	1,964	189.4
1966	1,992	190.0
1967	1,947	187.4
1968	1,962	188.2
1969	1,905	184.3

Sources:—1950-1968. *Taiwan Agricultural Yearbook, 1969 Edition,* Department of Agriculture and Forestry, June 1969, p. 21.

1969. Letter from C. L. Luh, Plant Industry Division, Joint Commission on Rural Reconstruction, Taipei, August 8, 1970.

rotations, with dryland crops rotating in between. Some pure vegetable rotations involve six to seven crops a year. Due to timing problems in the more intense sequences, it is sometimes necessary to plant some crops between the rice rows before the rice is harvested.[117]

A significant portion of some crops are produced as second, third or fourth crops on paddy fields. In 1968, the following proportion of total production of each crop was raised in this way:[118]

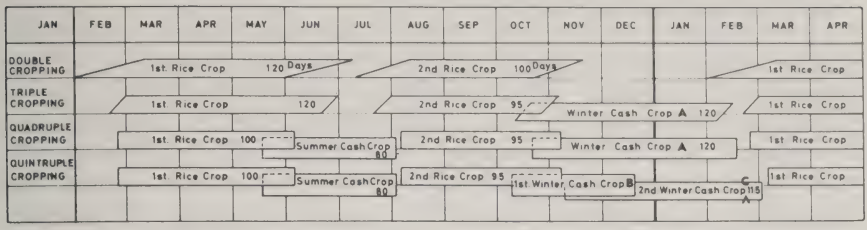
Wheat and Flax	100%
Tobacco	99
Soybean	81
Vegetables	51
Corn	42
Sweet Potatoes	14
Sugar Cane	9

[117] Peter Kung, "Multiple Cropping in Taiwan," *World Crops,* May/June 1969, p. 129; Cheng, *op. cit.,* pp. 7-8.

[118] Cheng, *op. cit.,* p. 9.


FIG. 6 MULTIPLE CROPPING SYSTEM OF PADDY FIELDS IN TAIWAN, CHINA
THE FIRST RICE CROP
THE SECOND RICE CROP
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
WINTER CROPS
SUMMER CROPS
WINTER CROPS
JUTE
LATE APRIL
EARLY AUGUST
(RELAY PLANTING)
MELON
LATE MAY
EARLY AUGUST
(RELAY PLANTING)
SOYBEAN
EARLY JUNE
LATE JULY
(RELAY PLANTING-TABLE USE)
PAI TSAI
JUNE
JULY
SWEET POTATO
EARLY MAY
EARLY AUGUST
(RELAY PLANTING)
WATERMELON
LATE MAY
EARLY AUGUST
(FOR SEEDS)
ORIENTAL PICKLING MELON
EARLY JUNE
EARLY AUGUST
(RELAY PLANTING)
SESBANIA
JUNE
EARLY AUGUST
(GREEN MANURE)
TOBACCO
LATE SEPTEMBER
EARLY FEBRUARY
(RELAY PLANTING)
CORN
MID OCTOBER
EARLY FEBRUARY
(RELAY PLANTING)
SOYBEAN
MID OCTOBER
MID FEBRUARY
(RELAY PLANTING)
PEAS
LATE OCTOBER
LATE FEBRUARY
(TABLE USE)
RAPE
MID OCTOBER
EARLY MARCH
(RELAY PLANTING)
SWEET POTATO
LATE SEPTEMBER
LATE FEBRUARY
(RELAY PLANTING)
VEGETABLES
MID OCTOBER
MID FEBRUARY
(RELAY PLANTING)
MILK VETCH
LATE OCTOBER
EARLY FEBRUARY
WHEAT
LATE OCTOBER
LATE FEBRUARY
FLAX
LATE OCTOBER
EARLY MARCH
PREPARED BY JCRR.
BASED ON FARMING PRACTICES ADOPTED IN TAICHUNG DISTRICT, TAIWAN

Figure 7. Changes in Cropping Patterns Involved With Higher Intensities of Multiple Cropping, Taiwan



Key to crops:

Winter Crop A
: Wheat, barley, buckwheat, maize, soybean, sweet potato, rapeseed, field pea, tobacco, flax, green manure crop (green bean), broccoli, cauliflower, Chinese cabbage, or tomato.

Winter Crop B
: Native cabbage.

Winter Crop C.
: Wheat, maize, broccoli, cauliflower, Chinese cabbage, or fieldpea.

Summer Crop
: Oriental pickling melon, Japanese cantaloup, jute, sweet potato, soybean, green manure crop, or native cabbage.

Source:—Peter Kung, "Multiple Cropping in Taiwan," *World Crops*, May/June 1969, pp. 128-130.

Crops not raised in this way may be produced as part of rotations on upland or dryland fields.

THAILAND

Although multiple cropping has been practiced in certain areas in Thailand for many years, as of 1970 the area was still quite limited. Overall, it probably represents considerably less than 1% of the planted area.[119] In certain zones such as the concentrated corn area in the central highland, however, it may account for up to two-thirds of the cropland.[120] The area in off-season paddy in the Central Plain was reportedly 6,200 acres in 1963 and 123,600 in 1968.[121] Vegetables are grown year-round in the Bangkok area; in Chiengmai region they are raised between rice crops.[122]

With the construction of the Chainat Dam and the Chao Phya Delta Project, the area multiple cropped increased from 67,700 acres in 1966 to 188,600 in

[119] T. H. Silcock, "Thailand," in *Agricultural Development in Asia* (ed. by R. T. Shand), University of California Press, 1969, pp. 125-126.

[120] Letter from Delane E. Welsch, Agricultural Economist, The Rockefeller Foundation, Bangkok, January 7, 1971.

[121] Shigeru Ishikawa, *Agricultural Development Strategies in Asia: Case Studies of the Philippines and Thailand*, Asian Development Bank, Manila, 1970, p. 84 (fn. 96).

[122] C. L. Luh, "Report on Vegetable Production Survey in Southeast Asian Countries," Seminar on Food Problems in Asia and the Pacific, Honolulu, May 1970, p. 12.

1967; both rice and upland crops were involved. In 1970 it was reported that the potential had been created to supply water to dry season crops over 153,000 acres; the goal for 1974 is 544,000 acres (of which 198,000 will be in rice and 346,000 in other crops).[123]

As we have noted earlier, there has been considerable debate as to whether rice or other crops should be planted on the newly irrigated land.[124] The debate may be nearing an end, however; a recently completed land use classification has shown that in the northern part of the Chao Phya Project no more than 12% of the land is suitable for irrigated production of crops other than rice in the dry season. Other uses of water, furthermore, seem to have high priority; these include hydroelectric power, navigation, and salt water extrusion.[125]

Several studies of multiple cropping are now underway. The Department of Agricultural Economics at Kasetsart University has been examining systems involving corn and sorghum. A survey of over 50 farms in one region revealed that the cropping intensity was 168 in 1968 and 163 in 1969. The proportion of land double cropped seemed to change quite a bit from year to year; in part this was related to variations in amount of land rented.[126]

The Ford Foundation is sponsoring multiple cropping studies at Chiengmai University. The work started in January 1969 and through the fall of 1970 focused on the development of four prospective rotations, each requiring different levels of fertilization and management (Table 28). An effort is being made to develop labor-intensive rotations, but in some cases machinery is needed for seedbed preparation, seeding, and harvesting. Initial emphasis is being placed on vegetables, particularly those that may be processed. An economist is being added to the consultant staff to help appraise production costs and market potentials.[127]

A research project has also been initiated at the Chao Phya Regional Research and Extension Center at Chainat with the assistance of the Australian Government under the Colombo Plan. Other groups and nations working on projects which contribute, in various ways, to multiple cropping knowledge include FAO, Israel, and the University of Kentucky.[128]

VIETNAM

Double cropping in Vietnam has been traditionally concentrated in the Tonkin Delta in what is now North Vietnam, and the Central Lowlands in South Vietnam.

[123] Ishikawa, *op. cit.*, pp. 75 (fn. 82), 82.

[124] Silcock, *op. cit.*, (1969), pp. 134-135.

[125] W. Van der Kevie, "Soil Landscapes and Potential Land Use in the Central Plains," *Thai Journal of Agricultural Science*, January 1970, pp. 1-12.

[126] "Multiple Cropping Systems Which Included Corn and Sorghum in Amphoe Phayuha Khiri, Changwat Nakhon Sawan, in 1968 and 1969," Kasetsart University, Department of Agricultural Economics, 1970. Also see Brook Greene, *Rate of Adoption of New Farm Practices in the Central Plains, Thailand*, Cornell University, Department of Agricultural Economics, Occasional Paper No. 41, July 1971.

[127] Letters from Dwight C. Finfrock, Project Specialist, Multiple Cropping Management, The Ford Foundation, Bangkok, September 4, 18, 1970.

[128] Finfrock, *op. cit.*, December 18, 1970; Welsch, *op. cit.*

Table 28.—Experimental Multiple Cropping Rotations
Chiengmai University, Thailand

Rotation No.	Cropping Sequence	Time Allocated to		Input Requirements	
		Growing	Turnaround	Nitrogen	Management Skill
1	Rice—wheat—sorghum	320	45	High	Low
2	Rice—tomatoes—peanuts	310	55[1]	Inter-mediate	Inter-mediate
3	Rice—peas—soybeans—snapbeans	340	25[2]	Low	High
4	Rice—potato—sweet potato—sweet corn	370	-5[3]	High	High

[1] Requires more time to clean up field after the tomato crop, and peanut harvesting is slow.

[2] Pea plants will be pulled and carried out of field; area will be power tilled and planted to soybeans as fast as peas are removed. The same system will be used to remove the soybeans and plant the snapbeans.

[3] Sweet corn interplanted 25 days before sweet potato harvest.

Source:—Letters from Dwight C. Finfrock, Project Specialist, Multiple Cropping Management, The Ford Foundation, Bangkok, September 4, 18, 1970.

North Vietnam

In North Vietnam, about 2.17 million acres were reportedly double cropped in 1960.[129] This represented about 47% of total cultivated land or a cropping intensity of 147.[130] Of the double cropped area, a little over ¾ was double cropped to rice and approximately ¼ was devoted to a rotation of rice and some other crop. The government had an ambitious program to increase both the double and triple cropped area by 1965 but it is doubtful that much expansion took place.[131] Gourou, in a study of the Tonkin Delta first published in French in 1936, reported observing triple cropping of several types (rice—rice—dry crop; dry crop—dry crop—rice; rice—rice—rice) and in exceptional cases, four crops.[132] More recent examples of triple cropping in Thai Binh province have been noted by Chaliand.[133]

[129] Marion R. Larsen, *Agricultural Economy of North Vietnam,* U. S. Department of Agriculture, ERS Foreign 123, April 1965, p. 10 (based on official statistics released in 1961).

[130] In 1961, Gourou indicated that 50% of the Delta area produced two crops (Pierre Gourou, *The Tropical World: Its Social and Economic Conditions and its Future Status* (trans. by E. D. Laborde), Longmans Green & Co., London, 3rd edition, 1961, p. 101).

[131] Some of the problems involved in shifting the peasants to double cropping of rice are noted in Gerard Chaliand, *The Peasants of North Vietnam,* Penguin Books, 1969, pp. 83-84.

[132] Pierre Gourou, *The Peasants of the Tonkin Delta: A Study of Human Geography,* Human Relations Area Files, New Haven, 1955, pp. 405, 412.

[133] Chaliand, *op. cit.,* pp. 166, 174.

In South Vietnam, about 621,000 acres of paddy land were double cropped in 1960. Considering the total cultivated paddy area, this represented a multiple cropping index of about 112.5.[134]

Of the double cropped area in 1960, about 543,600 acres (or 87.5%) were planted to a second crop of rice and 77,400 acres (or 12.5%) to other crops.[135] In 1966, about 568,000 acres of paddy were reportedly planted to a second crop of rice.[136]

Unlike North Vietnam, the major double cropped area was not found on delta land. Rather, about 80% of the area in 1960 was in the Central Lowlands (where the cropping index was about 166) and only about 20% was in the Southern Region (where the cropping index was about 103) which includes the Mekong Delta.[137]

A farm management survey of rice farmers during the 1968/69 crop year in the same two regions revealed the following proportion of cropped areas planted to a second crop of rice:

Region	*No. Farms*	*Double Cropped*
Central Lowlands	29	37.8%
Southern Region	113	5.5

Of the 113 farmers in the Southern Region, only 10 at the time were using IR-8 rice; however, 6 of the 10 produced a second crop.[138]

Within some portions of the Mekong Delta itself, the situation has evidently changed sharply in recent years. Sanson indicates that while less than 5% of the total Delta land was double cropped in the late 1950's, by 1966 about 41% of a sample group of farmers raised a second rice crop and another 14% grew field vegetables. In addition, some farmers had a pure rotation of up to four garden vegetables.[139]

The increase in cropped area in the Delta was due to greater use of fertilizer, increased availability of second crops with shorter growing seasons, and development of a water pump. The pump played a particularly important role in making the production of winter vegetables possible. Field vegetables (such as melons, squash, and tomatoes) were more easily grown on winter rice land than garden vegetables (onions, cabbage, lettuce, peppers and mint) which

[134] Computed from data in *Report on the Agriculture Census of Vietnam, 1960-1961*, Department of Rural Affairs, Agricultural Economics and Statistics Service, Saigon, pp. 42, 48-61. (This report was kindly brought to my attention by Nancy Hancock of ERS.)

[135] *Ibid.*

[136] Yamada and Lusanandana, *op. cit.*, p. 26.

[137] *Agriculture Census, op. cit.*, p. 48.

[138] Ray S. Fox, "Rice Cost of Production in Vietnam, 1968/69," US/AID, Office of Associate Director for Food and Agriculture, March 1971, Table 1.

[139] Robert L. Sanson, *The Economics of Insurgency in the Mekong Delta of Vietnam*, MIT Press, 1970, pp. 77, 78, 88.

required land conversion. The greater cultivation of a second crop reportedly permitted ". . . a major increase in the level of family incomes."[140]

Subsequent programs in upland areas of the country have focused on introducing such second crops as grain sorghum.[141]

* * *

The information and data provided in this section have provided only an introduction to multiple cropping in the countries listed. Hopefully further details will become available for both these nations as well as those not covered.

[140] *Ibid.*, pp. 87-88.

[141] Department of State Airgram A-1357 from Saigon, March 12, 1969.

VI. PROSPECTS AND POLICY ISSUES

Multiple cropping offers a third dimension to agricultural production—time. This dimension interacts with the two traditional methods of expanding agricultural output: the increase of area and/or yields. The result is that total output per unit of land is increased over the course of a year.

Although not a new concept—it has been practiced for thousands of years—multiple cropping is now the subject of increased interest. The reasons for this relate to both supply and demand. New early-maturing varieties, and associated inputs, have made it technically possible to increase the number of crops planted per year. Continued population growth and more limited increases in income provide a demand for an expanded and (to some extent) more varied output.

Concurrently, there has been a growing concern with the employment problem in rural areas as well as the need to improve the incomes of small farmers. Multiple cropping does increase the need for labor over the course of the year, though just how much is uncertain. And in many cases it can be carried out as well—or better—by small growers with underemployed family labor.

There are, therefore, strong reasons why less developed nations may wish to take a close look at multiple cropping.

PROSPECTS FOR MULTIPLE CROPPING

A vast array of factors influence the prospects for multiple cropping. But some regions or countries can clearly be eliminated as prospects because of unfavorable climate or other biological or physical limitations. In some cases these problems can be overcome, but at considerable cost; in these and similar areas multiple cropping may long remain a marginal question. For other nations or regions more fortunately situated, the time may not yet be quite at hand because of the need to improve water supply, the lack of adequate seasonal labor, or inadequate demand. But for still others the time may well be ripe for an expansion of multiple cropping.

Curiously, the Green Revolution, which has helped make increased multiple cropping possible, has probably also alleviated the immediate need for expansion in some regions. The increased yields from the new varieties in traditional seasons may have eased the need to move rapidly into new seasons. Thus, as Mellor suggested for India several years ago, the full effects of multiple cropping will probably be felt after the current direct impact of the dwarf varieties has become assimilated.[1]

[1] John Mellor, "Prospects, Problems, and Lessons," in *Developing Rural India: Plan and Practice* (by Mellor et al.), Cornell University Press, 1968, pp. 351-352.

Potential Multiple Cropped Area

Multiple cropping will doubtless grow in importance in the future. The expansion will, however, vary greatly between nations and regions within nations. So many interrelated factors are involved in multiple cropping that it would be very difficult to make any very precise projections of the potential multiple cropped area. Still, some general estimates as to the maximum global potential and possible shifts by continent have recently been prepared which may be of interest.

In the President's Science Advisory Committee (PSAC) report on the World Food Problem, the subcommittee on water and land estimated that multiple cropping could in effect ultimately expand the world's potentially arable land from 7.9 billion acres on a single cropping basis to the equivalent of 16.3 billion acres, more than double. Of this 8.5 million acre increase, however, only about 2 billion could take place in the absence of irrigation; attainment of the other 6.5 billion acres would require irrigation.[2]

FAO's recent Indicative World Plan acknowledged that while the potential for multiple cropping seems to be considerable, they don't expect it to assume major significance outside certain Asian and Near East countries before 1980. If suitable preparatory research is now begun, they feel that it could become "a major contributory factor to growth after that year in all developing regions where ecological conditions are suitable." It is noted that multiple-cropping could be of special significance in obtaining high financial returns from new investments in irrigation projects in Latin America and Africa south of the Sahara, even though population pressures on land would not render its general adoption as urgent as elsewhere.[3]

My reactions to the two projections differ. There is no possibility, as I see it, that multiple cropping could provide more than a fraction of the increase in effective crop area suggested in the PSAC report. Even if such an expansion were technically possible, it would require an enormous input of cash and scientific knowledge. And if the world ever gets to the point where its population requires such a massive amount of multiple cropping, it will be in an extremely sorry ecological state. The FAO statement seems to me to be a reasonable one, though lack of effective demand could limit adoption in areas where irrigation is being developed. The factors governing the expansion of multiple cropping are too many and too complex, I fear, to make it easy to precisely chart the geographical course of future progress.

Relation to Stage of Development

In assessing the prospects for multiple cropping, consideration must be given to the stage of development of the country.

From what we have seen, multiple cropping is usually a more complex process than traditional agricultural methods. It normally requires a relatively

[2] "Water and Land," *The World Food Problem,* The White House, Vol. II, May 1967, Chapter 7, p. 434. The statement on this point is not entirely clear, but I have checked my interpretation of the data with one of the members of the committee that prepared the chapter.

[3] *Provisional Indicative World Plan for Agricultural Development,* FAO, Vol. I, August 1969, pp. 132-133.

high degree of technical and management knowledge, an assured water supply, increased production inputs such as fertilizer and pesticides, and a more sophisticated marketing system. These ingredients are not available in great abundance in many nations, and are particularly scarce in the less developed nations. Therefore, climate permitting, the process technically might well be more easily adopted in the more advanced nations.

Other factors reinforce this point. Profitability to the farmer is a key item. For commercial multiple cropping to pay off, desire for the product must be backed up with the ability to pay for it at prices which will encourage production. In the least developed nations, the potential demand may be immense due to population growth and present low levels of food availability, but the effective demand is limited due to low incomes. Hence effective demand is apt to be greater in the more developed nations.

The demand, potential or real, will likely vary for different types of product. The lowest income groups may be glad to settle for basic food grains; their problem, as they see it, is to secure sufficient calories. The higher income groups, who already have access to grains, demand fruits and vegetables and dairy products.

The question facing the planner is to determine which income group he should try to reach, or to decide how to balance the emphasis between the two groups. Since low income groups might not have the purchasing power to buy additional grain even if it came on the market, a government purchase and distribution program could be necessary to encourage sharply increased monoculture involving grain crops. The existing price for fruits and vegetables might well be adequate, but the market may be thin—there are only a limited number of people able or willing to pay the price; the more highly developed the economy, the broader this group will be.

Hence from a supply and effective demand point of view, multiple cropping might naturally be expected to move more rapidly—other things being equal—in more economically developed nations. Government involvement, however, could alter this pattern.

Influence of Marketing Patterns

The prospects for multiple cropping will also be conditioned by marketing patterns. In most less developed countries, 50 to 90% of the economically active population is engaged in agriculture.[4] Much production is consumed on the farm. The proportion marketed typically increases with agricultural development (and a decrease in the proportion of the population engaged in agriculture). Thus there are both non-commercial (household) and commercial outlets for farm production.

Much of the motivating force for multiple cropping will probably come from the desire to sell the extra production for cash. Where the additional crop is the same as the basic crop (monoculture), relatively few changes in marketing practices may be necessary except those brought about by an increase in or a change in timing (such as the need to dry rice which may

[4] *Yearbook of Labor Statistics, 1965*, International Labor Office, 1966, Table 2A, pp. 40-131. Major LDC exceptions included Iraq (48), Cuba (42), Jordan (35), Venezuela (32), Chile (28), Argentina (19), Uruguay (18).

mature during the wet rather than dry season). Where different crops are to be produced, considerable changes may be necessary.

In either case, even greater modifications will be necessary if there is an intention to find an export market. Quality and grading standards may have to be raised. Processing, a relatively complex process, may be required to physically move the product or to find a market. Taiwan has made notable accomplishments in marketing canned asparagus in the U.S., but its success is more apt to be the exception than the rule. While exported foods will not be directly available to improve local diets, the added returns from their sale will enable the producer to buy other foodstuffs.

The government may well find that it will need to adjust its price support and purchase programs, which generally include only basic grains, if it wants to encourage production of other crops. The support prices for wheat in India and Pakistan, for instance, are high by world standards and may provide a disincentive to produce other crops. But lowering them may not be enough; some kind of guaranteed price program may be necessary at first to stimulate production of other crops.

Assuming a real or potential effective demand for the product exists somewhere, at a reasonable level, the marketing problems become more technological. That is, they become more intertwined with methods and facilities for drying, storing, transporting, distributing and the like. In some cases, multiple cropping may ease problems; since a crop is being produced more frequently the rate of flow to market is balanced out some, providing a more even demand for marketing services and possibly lessening the need for long-term storage. Still, I suspect the more normal situation will be for physical aspects of the marketing processes to become more complicated, especially if new and highly perishable crops are grown.

POLICY ISSUES IN MULTIPLE CROPPING

Any technological innovation is likely to have a wide range of ramifications. This is particularly true of a major innovation such as multiple cropping, which represents a package of technologies. These ramifications can have short and long run implications and can be primary and secondary in nature.

We shall briefly discuss four closely interrelated categories of policy issues: economic, social, ecological, and political. The main features of the economic and social categories have been previously introduced. The ecological ramifications are often overlooked but can be of major importance. And because of the economic and social distortions which can be introduced by technological change, multiple cropping may not be without political significance in some nations.

Economic Considerations

Assuming a nation is interested in expanding the quantity and quality of its food supply, is multiple cropping the best approach? Or would resources be more effectively used in traditional approaches involving expansion of area or yields? There is no one categorical answer. It might well vary with the conditions found in individual regions of a nation. In some favored regions, multiple cropping may be a clear choice; in more marginal areas, traditional practices might better be used for some time to come.

Infrastructure costs need to be taken into consideration in weighing alternatives. Expansion of yields and areas under any system, however, usually necessitates improvements in technical knowledge and education, water control, provision of other inputs, marketing of products, and the like. Expansion of cultivation into previously untilled land, moreover, could involve resettlement of individuals, construction of new homes, roads, marketing facilities, etc. Multiple cropping, on the other hand, can be practiced on existing farms, often as easily on small as well as large farms, by the present farm family.

In evaluating the economic potentials of multiple cropping, thought needs to be given to the economic dimensions of the various rotations which might be involved. Which would be most desirable in terms of national food policy? For example, is further expansion of existing grain crops desired (monoculture) or is it preferable to produce nutritious alternative crops such as pulses and vegetables? Could certain crops provide import substitution or export possibilities? Do some combinations have important complementarities? Which combinations would require the greatest government investment in infrastructure or price policy? Which would do most to raise farm income? There will not be perfect freedom of choice because of agronomic limitations, but economic factors could well influence the choice of crops to be emphasized.

While the planner may use a rather broad set of economic criteria, the farmer is apt to view the matter more narrowly. For him the economic question is usually simply whether the process is sufficiently profitable to go through with the considerable extra work that may be involved. The larger farmer who employs labor may, however, have a different set of opportunity costs than the small family farmer who has underemployed family labor available.

There are far more economic questions presented by multiple cropping than answers. While analytical tools, such as linear programming, are available which could be of great help, their use in many cases must await the availability of considerably more data on technical coefficients and opportunity costs.

Social Considerations

The social implications of multiple cropping can be quite complex. In the short run, the process can mean a restructuring of the annual calendar for the farm families as leisure or underemployment (depending on how it is viewed) is reduced. Hence it may be resisted. Moreover, the farm family may find that through multiple cropping it is inexorably led to the market economy, which in turn can lead to other social changes.[5]

Although multiple cropping is not wholly confined to irrigated areas, there are only relatively limited areas with sufficient natural rainfall. This means that multiple cropping is usually found in what are already the better agricultural areas within a nation. There are considerably fewer opportunities for farmers

[5] Critchfield, for instance, notes that "when an economic system uses money, it is not long before the value system begins to depend on money too." In the traditional village, where the social structure is based on mutual interdependence, this tends to displace human values. (Richard Critchfield, "Green Revolution Most Significant of Decade," *Washington Post*, December 27, 1970; reprinted in *Congressional Record*, December 30, 1970, pp. S21485–S21486.)

who live in nonirrigated or low rainfall areas. Consequently, existing social disparities can be widened further.

Within the multiple cropping area, the benefits may also be spread unevenly. Land owners with liberal access to water supplies or other factors of production are likely to fare better than the tenant or renter who sees his rent rise apace with increased multiple cropping. The effect on the landless laborer is less clear. To the extent that multiple cropping increases net labor needs outside the farm family, his lot will be improved; but if the system of payment is changed from a share of the crop to a cash payment, grazing rights are lost, and other social changes follow in the village structure, his position may be relatively worsened.

The longer-run implications are, depending on one's point of view, either encouraging or questionable. Multiple cropping clearly offers the opportunity for small farmers to significantly increase the quantity and variety of food supplies. At the same time, however, its expansion often has been closely associated with population growth. If multiple cropping only helps stimulate further population increase, with no improvement in diets, its long-term contribution to society may be questioned.

Ecological Considerations[6]

Virtually all technological innovations have ecological implications. Since multiple cropping is made possible through the use of several technologies, its possible ecological ramifications are particularly great. They may be reviewed in terms of the direct short-term implications and the more indirect long-term effects.

The cause of the direct effects is clear. The fact that one or more additional crops are grown on the same piece of land in a year means that not only is the fallow period reduced but that additional inputs must be utilized. Soil fertility must not only be restored but expanded. The presence of additional crops provides food or hosts for insects and diseases. Weeds have a longer growing period. Soil cover may be removed and erosion increased.

To some extent, these effects can be countered. Farm chemicals can restore soil fertility and can go a long way toward controlling insects, diseases, and weeds. But they do so at a direct financial cost to the operator (none is free) and at longer-run ecological costs. Fertilizers themselves are not destructive but their residue affects the chemical levels of run-off waters. Insecticides, pesticides, and herbicides leave residues which can build up to harmful levels in animals and humans. This can directly affect the producers' food supply where fish are raised in irrigation channels and flooded rice fields.[7]

[6] An international "Conference on the Ecological Aspects of International Development" held in Warrenton Virginia in 1968 produced considerable material on this subject which was reported as follows: "The Unforseen International Ecologic Boomerang," *Natural History,* February 1969, pp. 41-72; "Development in the Poor Nations: How to Avoid Fouling the Nest," *Science,* March 7, 1969, pp. 1046-1048; "Conference on the Ecological Aspects of International Development," *Nature and Resources* (UNESCO), June 1969, pp. 5-12.

[7] The use of herbicides in rice fields in Malaysia has led to spinal paralysis of fresh-water fish and a "not unwarranted suspicion of all pest control measures" in the Muda River Project area. An additional problem is that the twice-yearly flooding and draining of fields associated with double cropping may interfere with the breeding cycle of the fish ("Muda River Project," *World Crops,* March/April 1969, p. 16).

Water can, of course, be added through irrigation, but even here there may be ecological costs. Canal irrigation combined with imperfect drainage has caused severe salinization problems in India and Pakistan. The Aswan Dam in Egypt prevents the annual flooding of the Nile—which left a deposit of silt that both renewed the soil and built up the shore in the Mediterranean—exacerbating problems which began when perennial irrigation was substituted for flooding. The silt-free water released by the dam also may seriously scour the river bed.[8]

Other problems more directly affect humans. They stem from both reservoir and slow-moving canal water. Walton notes that:

> Where the irrigated areas coincide with dense populations at subsistence level it is difficult to control the endemic diseases which are related to flowing and free-standing water in a hot climate.

He specifically refers to malaria ("a major problem since irrigation farming was first attempted in the riverine lands and deltas") and bilharziasis ("which is of equally long standing"), and notes that "problems of irrigation and public health thus go hand in hand."[9] Recent reports of health problems have underscored the importance of this point.[10]

The degree to which multiple cropping may have influenced soil structure or erosion is not clear at this point. If a tilled row crop is grown instead of a cover crop, there is somewhat greater chance for soil and wind erosion. More frequent tilling would seem likely to break down soil structure more rapidly. These particular problems, however, may be less severe where flood irrigation is practiced than where reliance is placed on natural rainfall.

While it is not difficult to spell out possible ecological problems associated with multiple cropping, it is much more difficult to say whether these problems would be more serious than under other methods for expanding the quantity and quality of agricultural output. They may well be different, but we cannot be at all sure that they would be greater in any total sense. In some—perhaps many—cases, multiple cropping may cause fewer ecological problems than other approaches.

Political Considerations

The political implications of multiple cropping, if any, are a matter beyond the scope of this report. However, it might be noted that a study in India has suggested that the communist party is strongest in areas of very dense populations and intensive agriculture, where there are small holdings, high rates

[8] The ecological problems caused by the dam are currently a matter of some debate. Claire Sterling recently presented one side in a four-part series in the *Washington Post* in February 1971: 15, p. A18; 17, p. A18; 20, p. A14; 24, p. A18. The scouring problem was also discussed by her in the *Post*, December 29, 1970, pp. 1, 12. A rebuttal by the Arab Information Center was published in the *Post* on March 26, 1971, p. A27.

[9] K. Walton, *The Arid Zones*, Hutchinson University Library, London, 1969, p. 132.

[10] See: Claire Sterling, *op. cit.* (Feb. 17), and "Super Dams Pile Up Myriad Problems," *Washington Post*, January 6, 1971, p. A23; "Schistomiasis; The Disease of Slowed-Down Waters," and "Kariba Dam: The Ecological Dangers of Making a Lake," *Natural History*, *op. cit.*, pp. 62-72.

of tenancy, and a high degree of landless laborers.[11] This suggests that in densely-populated areas where multiple cropping is to be increased, non-communist governments may wish to give special attention to land reform and the plight of the landless laborers.

NEED FOR FURTHER RESEARCH

This report has hopefully made abundantly clear the need for further research of many types and at many levels on multiple cropping. There is a need to better evaluate the prospects for multiple cropping as well as the best way to carry it out, if it is found promising. Both short and long range implications must be evaluated, the immediate effects on the improvement of the food supply and employment balanced against longer-run ecological consequences. Both primary and secondary effects must be analyzed.

The natural tendency may be to start research work from an agronomic point of view, and then move gradually into farm management types of research. Both are certainly necessary, but not—to my mind—sufficient. Much more must be done. The goals for multiple cropping must be established within the context of national economic goals and the stage of development of the individual nation. Marketing patterns need to be analyzed and possibly improved. Policy implications and requirements must be studied. In addition to the broad range of economic factors which need to be examined, numerous social, ecological and political considerations should be brought into the balance.

To do all of these things properly will, unfortunately, require a greater depth and wider range of research capabilities than are present in most less developed nations. Further scientific studies at international institutes could help establish more general guidelines, while a better exchange of national studies and experience may provide insights for local application. The problem is in a sense an economic one: to make the most efficient use of what will undoubtedly continue to be very limited resources.

Although multiple cropping is thousands of years old, it provides considerable potential for helping meet some major contemporary problems. For this potential to be realized, however, much more study of both a biological/physical and social/economic nature will be needed.

[11] Donald S. Zagoria, "The Ecology of Peasant Communism in India," *American Political Science Review*, March 1971, pp. 144-160. Also see Francine M. Frankel, "India's New Strategy of Agricultural Development: Political Costs of Agrarian Modernization," *The Journal of Asian Studies*, August 1969, pp. 693-710.

VII. APPENDIX

A. MULTIPLE CROPPING IN THE UNITED STATES

Aside from Japan, only limited areas are known to be double cropped in the developed nations (although large areas may be planted to cover crops). The most common forms may be market gardens and greenhouse operations. Here we shall review what little information has been found on field operations for the United States.

Multiple cropping is carried out in several regions of the United States, but we have no direct estimates of the area involved. Agricultural census data, however, can be used to derive an outside estimate. As Table 29 indicates, the area may have averaged around 5 million acres and the index nearly 102 during the post-World War II period. The exact regional and commodity composition of this area is not reported.

Double cropping rotations involving winter wheat or barley followed by grain sorghums have evidently been practiced in southern portions of the United States for 40 to 50 years. More recently, soybeans have joined sorghums as a second crop. In some of the southeastern states, double cropping involving a wheat-soybean combination is almost a necessity because wheat alone is not sufficiently profitable. The practice has been facilitated by the presence of the combine harvester. In more northern states, buckwheat may be sown after early harvested small grains.[2]

Several variants of double cropping are also practiced in several of the rice growing areas. In Arkansas, there is a large area where fall-sown oats are overplanted with lespedeza in February; the oats are harvested for grain in May and the lespedeza is harvested for seed in the fall. In Texas, a second ratoon crop is grown; Bluebelle rice is sown about April 1 and harvested in late July. The field is then fertilized and rewatered and the ratoon crop is ripe in October.[3]

Specialized multiple cropping operations are found in Florida, Alabama, and California. They usually involve vegetables.

[1] Annual data are published by the U.S. Department of Agriculture which may be used to derive an estimate of the multiple cropped area. They are, however, based only on interpolation of census data. The actual numbers differ from the census data for individual years due to differing commodity composition and other adjustments. (*Changes in Farm Production and Efficiency, A Summary Report, 1970,* Statistical Bulletin No. 233, June 1970, p. 6.)

[2] Letters from: John H. Martin, Corvallis, Oregon, July 25, 1970 (Mr. Martin is a retired USDA plant scientist); K. L. Lebsock, Research Agronomist, Agricultural Research Service, USDA, Beltsville, May 26, 1971.

[3] Letter from C. Roy Adair, Leader, Rice Investigations, Agricultural Research Service, USDA, Beltsville, May 26, 1971.

Table 29.—Multiple Cropped Area and Indexes, United States

Year	Assumed Area Multiple Cropped[1]	Assumed Cropping Index
	(1,000 acres)	
1929	2,861	100.8
1934	3,018	101.0
1939	2,963	100.9
1944	489	100.1
1949	6,504	101.9
1954	5,156	101.6
1959	4,783	101.5
1964	4,748	101.7

[1] This figure is a residual and is calculated by subtracting the total area of all crops harvested from the area of cropland harvested.

Source:—*1964 United States Census of Agriculture,* Vol. II, Chp. 4, pp. 290, 301.

— Florida. Most of the multiple cropped area in Florida is devoted to monoculture, at least for individual years. The crops most frequently double cropped include sweet corn, snap beans, and tomatoes. Radishes may be triple or quadruple cropped. On a double cropped basis, the four crops involve approximately 30,000 acres. Other commercial cropping sequences include squash-squash or beans or pepper, pepper-beans and cucumbers-pepper. The main regions involved are Dade, Palm Beach-East Broward, Hendry-Lee, Ft. Pierce, Everglades, and Sanford.[4]

— Western Florida/Alabama. In one area, early potatoes are followed by soybeans.[5]

— California. Multiple cropping is principally found in portions of the Salinas, San Joaquin, and Imperial Valleys. While some of the lettuce land in the Salinas Valley has a cropping index of 150 to 200, the overall index for the Valley may be no more than 100. In four irrigation districts on the west side of the San Joaquin Valley, the cropping index varied from 101 to 108 in 1969. The overall index for the Imperial Valley in the 1968 crop year was only 101.4.[6]

Further study of multiple cropping in the United States might well be in order.

[4] Conversation with Donald Brooke, Dept. of Agricultural Economics, University of Florida, January 6, 1971; letter from Brooke, June 4, 1971.

[5] Adair, *op. cit.*

[6] Letter from Charles V. Moore, Farm Production Economics Division, Economic Research Service, Davis, California, January 12, 1971. A survey of 160 farmers in the Salinas Valley in 1964 showed 69,235 crop acres on 69,821 irrigated acres. In the Imperial Valley irrigation district, 435,806 crop acres were reported on 429,594 acres of irrigated land.

B. MAXIMUM PRODUCTION UNDER RICE TRIPLE CROPPING

The International Rice Research Institute has conducted experiments involving triple cropping of rice since 1962.[7] They provide some indication of the current upper limit of rice production per unit of land. Adequate water was available year-round.

The highest total production for any single variety or line at the Institute farm, as of 1969, was obtained from broadcast IR-8: a total of 21.08 metric tons per hectare. Yields of individual crops were 8.84, 5.53, and 6.72 metric tons per hectare respectively. The total growing period was 344 days; 21 days were available for preparing the land.

In another experiment at the Institute farm involving different lines, the highest total yield obtained in 1969 was 23.04 mt/ha.; The individual crops were (1) broadcast IR-8, 8.12 mt/ha.; (2) broadcast IR-593-3-17, 7.86 mt/ha.; and (3) transplanted IR-661-1-140-3, 7.06 mt/ha. The total growing period was 350 days.

In a cooperative study conducted at the Central Mindanao State University in 1969, the highest total production for a single variety was 23.55 mt/ha. This was, according to the IRRI report, the highest such total obtained anywhere in the world. Transplanted IR-593-3-17 was involved, and the total growing period was 315 days. IR-20 produced 23.23 mt/ha. in 300 days, while IR-8 produced 23.83 mt/ha. in 316 days.

[7] The data reported here were obtained from *The International Rice Research Institute Annual Report, 1969*, pp. 110-111.

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